

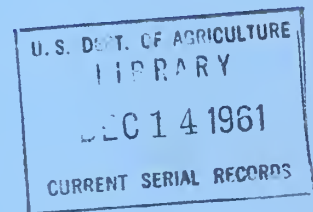
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An Evaluation of
Basal Metabolic Data

**for Children and Youth
in the United States**



Home Economics Research Report No. 14

Agriculture Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

3
An Evaluation of

Basal Metabolic Data

for Children and Youth
in the United States

20
by Dorothy Worstell Sargent

7a Home Economics Research Report No. 14



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An Evaluation of

Basal Metabolic Data

for Children and Youth in the United States

By Dorothy Worstell Sargent, *Human Nutrition Research Division, Agricultural Research Service*

I.—Background of the Study

Basal metabolic data are useful to nutritionists as a basis for estimating optimal food energy requirements of a person or of a population group; they are useful to physicians as diagnostic aids in diseases of the thyroid; and they are useful to physiologists as aids to a better understanding of the bodily processes.

However, confusion results from the accumulation of original standards, modified standards, and revised standards for basal metabolism which are not in agreement. A brief history of the development of these standards for children follows.

The first standards for basal metabolism were proposed by Aub and Du Bois in 1917. Previously Du Bois (1916) had presented a smooth curve in terms of Calories per unit of body surface for males 1 to 80 years of age. However, owing to the paucity of data for the younger children, the "Aub and Du Bois," or "Sage," Standards presented in 1917 began with age 14 years and presented data at 2-month intervals up to age 80 years, with the values for females calculated as 7 percent below the average for males.

In 1921 Benedict and Talbot published the results of their investigations on basal metabolism from birth to puberty. They concluded that weight was superior to surface area for predicting basal metabolism of children. Accordingly, their proposed standards presented Calories per 24 hours for each 0.5 kilogram of weight from 2.5 to 32 kilograms for girls and to 38 kilograms for boys. These standards are still used either in their original form or in a slightly modified form. The original values are considered too low, as they were based on the lowest values observed and many of the children were asleep. In 1925 Talbot proposed a table for predicting the basal heat production of children from birth to 12 years from height. This table was based on the data reported earlier by Benedict and Talbot. In a 1933 publication Talbot reproduced both of these tables.

In 1929 Boothby and Sandiford presented a

"modification of the Du Bois Standards," using the results from determinations made on 262 normal school children to extend the standards to younger ages (6 years). Later, the well-known Mayo Foundation Standards (Boothby *et al.*, 1936) were introduced for predicting basal heat production in Calories per square meter of body surface for ages 6 years and over. Values from these standards are generally considered to be too high, as the first value obtained on a given subject was used in setting up the standard.

In 1935 and in 1937 Talbot *et al.* introduced basal metabolic standards for girls in terms of total Calories for weight and for height. These standards were based on new data obtained on 85 private school girls combined with data published previously by Benedict and Talbot (1921).

In 1938 Talbot presented standards for girls that were stated to have been based on 2,200 observations. However, they were identical with those published in 1935 that were reported to have been based on 179 measurements. The 1938 standards for the boys were based on 800 observations, and were practically the same as the 1921 standards of Benedict and Talbot for boys weighing up to 18 kilograms; thereafter the newer standards were from 1 to 5 percent higher.

For the girls the 1935 and 1938 standards were slightly lower than those of 1921 up to 10 kilograms and thereafter were higher by as much as 6 percent. The standards for both boys and girls were extended for predicting basal heat production (Calories per 24 hours) for children weighing up to 84 kilograms.

Longitudinal studies made by the Child Research Council, Denver, Colo., have resulted in the establishment of new basal metabolic standards for both boys and girls. These were first presented in 1937 by Lewis, Kinsman, and Iliff and included ages 2 to 12 years. In 1943 Lewis, Duval, and Iliff published standards from a statistical analysis combining new data with the old and extending the age to 15 years. Recently, another statistical analysis was made but not pub-

lished (*see* Iliff, n.p.): this included data obtained up to 1952 and extended the age to 25 years. These workers presented standard values for Calories per square meter of body surface that referred to age and Calories per hour that referred to weight, to height, and to surface area.

From longitudinal measurements on adolescent boys and girls, Shock (1942) presented average heat-production values, Calories per square meter of body surface per hour, for ages 11½ to 17½ years.

The foregoing standards are the ones that have been proposed for children in the United States. Several standards have appeared recently in Europe—from Denmark the standard values for boys were presented by Biering (1931) and for girls by Vogelius (1945), and from Britain the standards of Robertson and Reid (1952). Biering and Vogelius, as did Benedict and Talbot, considered weight the superior reference base for predicting heat production of children. However, Robertson and Reid followed the practice of Aub and Du Bois and the Mayo Foundation group of reporting basal heat production in terms of Calories per unit of body surface for a given age.

In addition to these standards, there have been numerous reports from other workers investigating the basal metabolism of children. For a review of this literature, *see* Lewis *et al.* (1937) and Vogelius (1945).

From this brief resumé of standards proposed in the past 40 years, it is obvious that questions confronting workers in the basal metabolic field today are which standard is the most reliable and which reference base should be employed? It is generally considered that the basal metabolic rate should be calculated by more than one standard (*see* Jenkins, 1932; Lewis *et al.*, 1937; Sherman, 1952). However, Watson and Lowrey (1951) pointed out that "the use of different standards by the several authors only adds confusion to an already confused picture." Some authors (Jenkins, 1932; Du Bois, 1936; Talbot, 1938) advocate that before a clinical laboratory accepts a given set of standard values, each laboratory should determine the basal heat production of a representative sample from its own locality and adjust the standards as the results indicate.

Contributing to the confusion is the practice of reporting results from basal metabolic studies only in terms of percentage deviations between the observed heat production and that predicted from some chosen standard. This practice not only gives the illusion that the standards are absolute rather than relative (*see* Jenkins, 1931), but makes impossible a comparison between the results of different investigators, unless the procedures and standards employed are the same. Furthermore, as Talbot, Wilson, and Worcester (1935) emphasized, the contribution to scientific data is worthless, unless the basic data are re-

ported along with pertinent information as to the methods used and the procedures followed in the investigation (*see* also Leitch, 1959).

In estimating energy requirements there is no substitute for the measurement of heat production. In clinical practice, however, the measurements of protein-bound iodine concentration, radioactive iodine uptake and excretion, and serum cholesterol are used for determining thyroid activity. While some reports (Roswit *et al.*, 1952; Werner *et al.*, 1950) advocate these newer techniques, others (Keating *et al.*, 1950; Keating, 1957) consider that they will be useful only as supplements to the long-established method of determining metabolism by indirect calorimetry.

In certain diseases these newer methods of measuring thyroid activity cannot be used (Jackson, 1957b). Furthermore, tracer doses of radioactive iodine may be harmful to children (Hubble, 1956). The advantages and limitations of each of these measurements have been discussed by many investigators (*see* Wilkins *et al.*, 1941; Skanse, 1949; Jaffe and Ottoman, 1950; Freedberg *et al.*, 1952; Silver *et al.*, 1955; Heald *et al.*, 1956; Keating, 1957).

The usual procedure employed in comparing the accuracy of basal metabolic determinations with that of other techniques for determining thyroid activity has been to calculate the percentage deviation from some selected standard. However, the degree of accuracy could well depend upon the standard used, and the choice of a reliable standard is a problem by itself. Consequently, the basal metabolic standards employed in comparing these newer measurements have been many. For example, Skanse (1949) reported his results on the basis of the Aub and Du Bois Standards first established in 1917; Peeler *et al.* (1950) used the 1929 Boothby-Sandiford modification of the Du Bois Standards; and Roth and Buckingham (1939) used the 1919 Harris-Benedict Normal Standards.

Recently, the 1952 Robertson and Reid Standards were used by Fraser (1956). Some investigators (Crooks *et al.*, 1958) used several standards for comparison and others failed to report the standards used. Therefore, it is not surprising that conflicting results have arisen as to the accuracy of these newer tests in comparison with the basal metabolic test. There also appears to be some disagreement as to the normal range of these newer measurements.

In this study we have compiled, analyzed, and integrated all available data on basal metabolism of children. The original data were obtained from as many investigators as possible to determine whether differences in results obtained by the various investigators could be attributed to differences in techniques and procedures followed, to differences in geographical locations, or to differences in physical characteristics of children from the various population samples.

II.—Recent Basal Metabolic Standards for Children

In figure 1 are shown the more recent basal metabolic standards for children for Calories per unit of body surface referred to age and for Calories referred to weight. The data collected for this summary (*see* table 1) have been confined to the United States; however, for comparative purposes, the recent British and Danish Standards also have been included.

Although the relationship between basal metabolism and age or weight is not a semilogarithmic (or exponential type) function, use of semilogarithmic paper (arithmetic horizontal scale and a logarithmic vertical scale) provided a means for comparing the variations between standards on a percentage basis (figure 1). Its use also prevented a possible distortion due to the wide difference in range of the vertical scales between the two reference bases shown—the average values for the boys range from about 15 to 80 Calories per hour in contrast with a range from about 35 to 60 Calories per square meter of body surface.

As equal vertical distances represent equal percentage changes anywhere on the chart, these charts indicate that the three standards with weight as the reference base are in closer agreement than the standards in which surface area for a given age is the reference base. The Mayo Foundation Standards (Minnesota) are from 8 to 16 percent higher than the Colorado Standards on the basis of Calories per square meter of body surface for all ages; whereas on the basis of weight the Danish Standards are about 5 percent higher than the Colorado Standards, except for girls weighing more than 40 kilograms.

Another feature brought out by figure 1 is that the parallelism between the curves is closer in the standards using weight as the reference base, especially between the Massachusetts and Danish Standards. The flattening of the curve (Calories in relation to weight) after 45 kilograms for the Colorado Standard includes girls up to 25 years of age, but the Massachusetts and Danish (Vogelius') Standards include data only to about 15 years.

Some of the differences among the standards shown may be attributed to the purpose for which the standards were intended; that is, for clinical or physiological use (Du Bois, 1936; Roth and Buckingham, 1939). The Mayo Foundation Standards are "clinical," in that they were based

upon data obtained from the first test (unless unsatisfactory) on inexperienced (untrained) subjects. The other standards are "physiological"; that is, they were based upon measurements on experienced subjects or upon the lowest values from a series of repeated tests. There is no uniformity among investigators as to what value should be used for reporting the results from basal metabolic studies (*see* table 1).

If experience or familiarity with the apparatus and procedure were to explain the difference between the clinical (Mayo Foundation Standards) and physiological standards, then the curves for the various standards should parallel each other for all ages (assuming that the effect of previous experience would be the same for all ages). At first glance there appears to be no parallelism between the curves shown in the upper sections of figure 1, but if the Mayo Foundation and Colorado Standards for Calories per unit of body surface in relation to age are compared, a near parallelism is evident. The Mayo Foundation Standards, based upon single tests on inexperienced subjects, are from 8 to 16 percent higher than the Colorado Standards, based upon measurements on experienced subjects. A smaller difference between the two standards is found at the younger ages.

In comparing the physiological standards the British Standards are from 3 to 12 percent higher than the Colorado Standards, with a greater difference occurring at the younger ages. Theoretically, the British Standards should be the lower, as they are based on the lowest values observed from repeated tests on successive days, whereas the Colorado Standards are based upon "satisfactory" measurements on experienced subjects.

A possible explanation for the difference between the British and Colorado Standards might be in the respective apparatus used; that is, the closed-circuit type giving higher values than the open-circuit chamber. Thus, if the type of apparatus influenced the results, each age group should be affected equally (at least on experienced subjects), resulting in a parallelism between the standards. This is not true either when the British are compared with the Colorado, the Danish with the Colorado, or the British with the California Standards.

The more recent basal metabolic standards

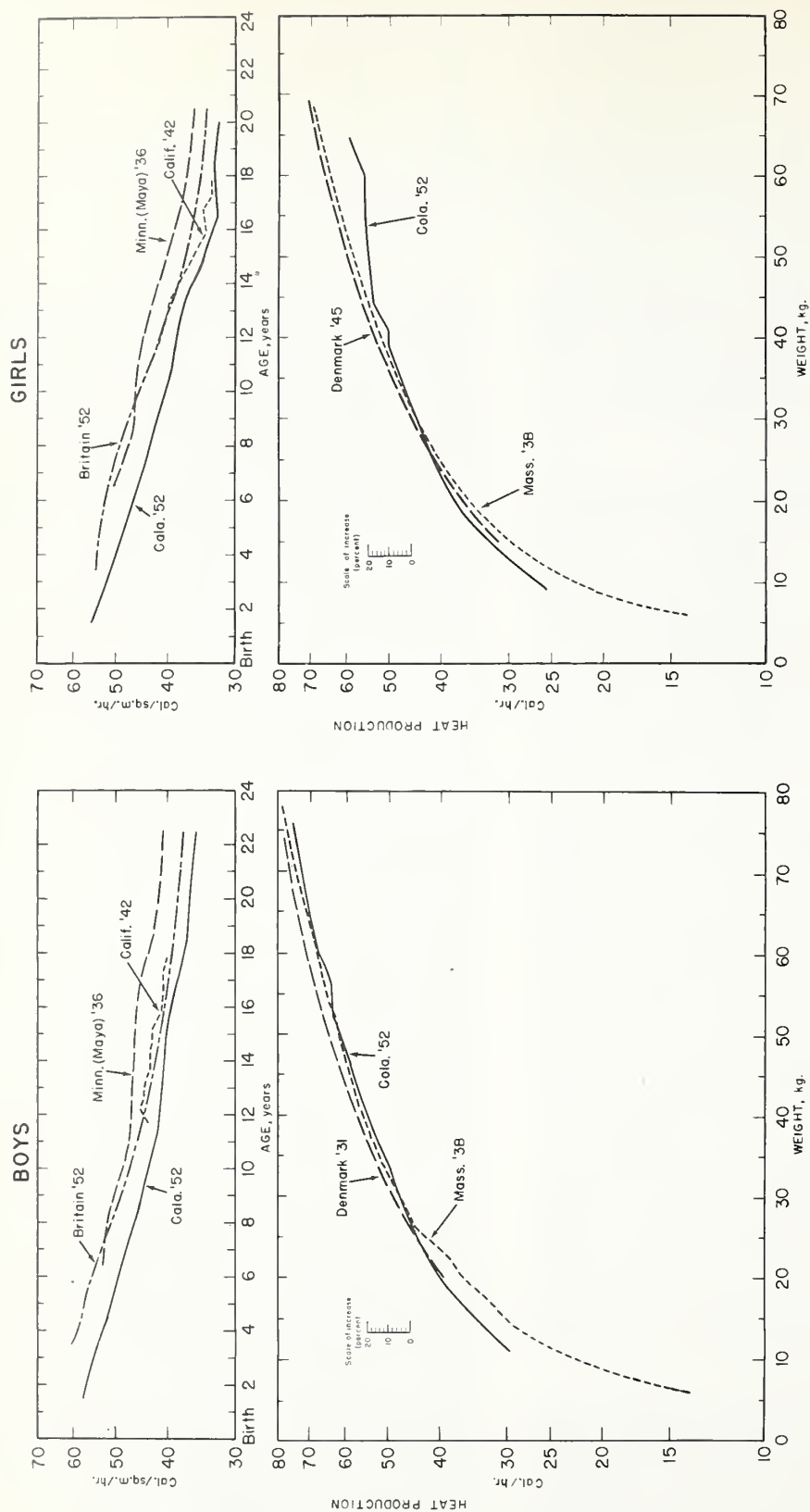


FIGURE 1.—Recent basal metabolic standards for boys and girls.

Standards using Calories per hour with weight as the reference base are shown in the lower sections and standards using Calories per unit of surface area per hour for a given age are shown in the upper sections. By using the scale shown, the percentage increase between any two curves may be estimated, as a logarithmic vertical scale is used. The curves for the standards have been "smoothed" except for the California Standards, which are the actual averages obtained. See table 1 for references, for apparatus, and for procedures used in obtaining the data for the standards.

TABLE 1.—References and details for basal metabolic standards shown in figure 1

Standard	Investigator(s) ¹	Type of apparatus	Values used to report a basal metabolic measurement	Subjects
Denmark, Boys-----	Bierring (1931)-----	Closed-circuit (Krogh)---	The mean of at least 4 tests (duplicate tests on successive days) which did not show any falling tendency.	133 boys, 7 to 18 years (each age group represented 11 boys), selected at random from different schools in Copenhagen. General clinical examination made.
Denmark, Girls-----	Vogelius (1945)-----	Closed-circuit (Krogh)---	Same as Bierring (<i>see above</i>)-----	121 girls, 7 to 15 years, from Rönne Elementary School, Denmark. General clinical examination made. (Children up to 18 years measured, but girls over 15 years not included in standard.)
Minnesota (Mayo Foundation).	Boothby, Berkson, and Dunn (1936).	Open-circuit with mask (Tissot gasometer).	The first test made for each subject unless it was "unsatisfactory" due to restlessness, nervous tension, or an elevated temperature.	296 normal boys and 251 normal girls, 6 to 18 years, from Rochester schools included in standard.
Massachusetts-----	Talbot (1938)-----	Closed-circuit (Benedict Portable or Chamber).	The average of tests checking within 5% of that obtained during another period; however, data published earlier by Benedict and Talbot (1921), in which the lowest observed value represented the basal, also were included (<i>see table 3</i>). An average of 3 8-minute tests made on 2 consecutive days after 2 trial tests on the previous day.	Standards made from smoothed curve from data on 2,200 girls and 800 boys—some "from my own cases and the rest from cases reported in the literature."
California-----	Shock (1942)-----	Open-circuit with mask (Tissot gasometer).		50 normal boys and 50 normal girls (11½ to 17½ years) from elementary schools in Oakland, Calif., measured semiannually for 6 years.
Britain-----	Robertson and Reid (1952).	Closed-circuit (Benedict-Roth).	The lowest test from a series composed of duplicate tests made on successive days and continued until the second of the 2 duplicate tests differed by no more than 5% from the first test of the same day.	Data for standards included 425 healthy children 3 to 18 years, inclusive. Study was begun in 1930.
Colorado-----	Iliff (n.p.)-----	Open-circuit chamber (Tissot gasometer).	One satisfactory test after a training period on unexperienced subjects. If the subject made more than an occasional slight movement, the test was considered unsatisfactory.	2,346 tests on 104 normal boys and 1,981 tests on 101 normal girls, 2 to 25 years, from private homes in Denver and vicinity measured at 3- to 5-month intervals. Study was begun in 1932.

¹ For Literature References, *see* section XI; "n.p." denotes not published.

showed (figure 1 with details given in table 1) that there were not only differences among investigators as to the reference base employed (which will be discussed in the following section), but also in the following: (1) The type of apparatus used: (2) whether or not the children

had had previous experience or training in having a basal metabolic measurement taken; and (3) the selection of a value for reporting basal metabolic measurements when more than one test is made. These differences in procedure of measurement will be discussed in section VIII, part A.

III.—Reference Bases Used for Expressing Heat Production

Many reports as to the relative merits of both body surface and weight as a reference base for basal metabolism (as well as for other physiological functions) have appeared in the literature since Harris and Benedict (1919) took exception to the Aub and Du Bois Standards (1917) that used surface area as a reference base. Harris and Benedict based their prediction standards upon multiple regression equations using weight, height, and age.

The controversy regarding body surface as a reference base applied to different physiological activities is as unsettled today as it was 40 years ago. For example, see Snively's (1957) report recommending body surface for estimating fluid dosage as contrasted with the report from Oliver, Graham, and Wilson (1958) refuting body surface as a reference base for fluid requirements or for any other physiological activity. It is not within the scope of this paper to discuss these arguments in detail. For a historical review of the formulation of the "surface law," see Du Bois (1936), Brody (1945, pp. 354-365), and Kleiber (1947).

By tradition, the standards presented in terms of Calories per unit of body surface for a given age (Aub and Du Bois, 1917; Boothby *et al.*, 1936; Lewis, Duval, and Iliff, 1943; Shock, 1942) have been accepted as being the most reliable ones for estimating the heat production in humans in this country (Best and Taylor, 1956; Peters and Van Slyke, 1946; Keys *et al.*, 1950; Sherman 1952). Body surface has been considered superior to either weight or height as a reference base, as it includes both weight and height, thus correcting for differences in body build.

The standards of Benedict and Talbot (1921) and Talbot (1938) referred to weight have also gained wide acceptance (Hawk *et al.*, 1954; Davenport *et al.*, 1939). These workers, and also Bierring (1931) and Vogelius (1945) in Denmark, considered that heat production was accurately predicted from weight and that there was no advantage in using surface area. Vogelius (1945) reported that "the surface area calculated on the basis of weight and height is encumbered with an uncertainty of ± 3 percent."

Recently, Durnin (1959) in Britain found from studies on energy expenditure of adults that body surface was no more useful than weight as a standard of reference. The 1957 report on caloric requirements by the Food and Agriculture

Organization of the United Nations stated that "basal metabolism can be estimated from body weight alone with an accuracy approaching that achieved from estimates of the surface area"; however, the recommended caloric requirements for children were given in reference to age, and it was recommended that no adjustment for body size be made in the requirements of children up to the age of 16 years.

It is generally considered that as long as the physical development of the observed subject is within the normal range of variability, it makes little difference which reference base is used (Wolman, 1946; Talbot, 1933, 1938; Lewis *et al.*, 1937, 1943). The difficulty in choice of a reference base occurs for the child whose weight and height for age deviate from that of the average child. For these children, Iliff *et al.* (1951) found that the standards based on Calories referred to either weight or to body surface were the most reliable, and the standards relating Calorie per unit of body surface for a given age were "also dependable except with very small children or dwarfs." Talbot (1938) concluded from his observations that "fewer mistakes result when the standard of total Calories for the weight supplemented by that of total Calories for the height (in other words, the total Calories for the 'expected weight') was used" for obese and undernourished children. However, Vogelius (1945) stated that for children outside the normal range "it is absurd to try to estimate the metabolism on the basis of the standard applying to normally-built children."

Although the difference of opinion appears to be centered around whether body surface or weight is the more reliable reference base to use for basal metabolism, the real problem is between age and weight. Wolman (1946) stated that age is the least satisfactory as a basis of reference. Hawk *et al.* (1954) pointed out that variations in the rate of growth and development in childhood cause abnormal results with the use of the age standards, whereas Vogelius (1945) pointed out that the method of expressing metabolism per unit of weight or per unit of body surface in relation to age "is wrong in principle and that in practice has led to misleading results" (see also Tanner, 1949).

That basal heat-production values expressed both in terms of Calories per unit of body surface and Calories per unit of weight in relation

to age show great irregularity and wide dispersion of individual points was shown by Benedict and Talbot (1921). They found no indication that age *per se* had any specific influence on the metabolism of children—age, weight, and body surface changes are all closely interwoven. However, Quenouille *et al.* (1951) concluded from a statistical analysis of basal metabolic data (for 17 to 39 year-old men and women but applied to younger and older ages) that “when all other variables have been taken into account, the massed data for adults of both sexes and all racial groups analyzed, and for the U.S.-N. European children, conform to the rule that basal metabolism declines at the rate of 3 percent per decade from age 3 to ages over 80.” Although the 1957 report of the Food and Agricultural Organization of the United Nations stated that the basal metabolic rate decreases regularly after the early twenties, no mention was made of a change in the basal metabolic rate for younger ages.

A logarithmic grid from which basal metabolism could be predicted along with body build (physique), developmental level, nutritional level, and caloric needs was developed by Wetzel (1941, 1944), mainly for use with longitudinal types of growth data. Bruch (1942) reported that this grid gave unreliable predictions. Eichorn (1955) applied the Wetzel grid to a group of adolescent children and found that basal metabolic estimates from the grid were consistently below the measured values for the boys and also for the girls under 14 years of age; thereafter, the grid values were higher than the observed basal metabolic values for the girls.

From 97 observations on 52 children 6 to 14 years of age, Talbot *et al.* (1939) computed equations relating caloric output to creatinine excretion and found these to be as highly correlated as the correlation between caloric output and weight. Since creatinine excretion is a measure of active muscle mass, they considered that a standard based upon creatinine output would be more accurate (although impractical for routine use because a 24-hour urine collection is required) for predicting heat production of children of abnormal body build.

Although some investigators (for example, Adams and Poulton, 1937) consider that height is the best reference base for estimating heat production in young children, it has not been used as extensively as weight or body surface. The tables prepared by Talbot (1933) and those by Lewis *et al.* (1937, 1943) were the only standards found using height as reference base. The Colorado workers found that height was not so reliable a reference base as weight or body surface but “because of its wide use in the literature,” they used height as a reference base in addition to weight, surface area, and age.

While the main argument in choice of a reference base for heat production has been centered around body surface, weight, age, and to a lesser extent, height, other methods of reference have been suggested. One of these was the width-height index (widest diameter of the crest of the pelvis divided by the height in percent) suggested by Lucas and coworkers (1931, 1932, 1933). On a selected group they found a higher basal metabolic rate in slender-built children (low width-length index) than in broad-built children (high index). Nevertheless, Molitch (1935) found no evidence of a correlation between oxygen consumption and the width-length index for 199 boys.

Considerable literature has appeared on the relation of body composition, or lean body mass, to metabolism. The use of “active protoplasmic mass” as a reference base originated in 1901 (*see* Brody, 1945, p. 363), and has been generally accepted as a logical reference base for metabolism (Talbot, 1933). The difficulty has been to find a method to measure or estimate the amount of metabolically active tissue (muscle and internal organs) or the amount of inactive tissue (fat, bone, and body fluids) in the body. Recently, the percentage of fat in the body has been estimated from measurements of body specific gravity, total body water, urinary creatinine excretion, soft-tissue radiographs, and skin-fold thickness (Brožek and Keys, 1951; Garn *et al.*, 1953; Miller, 1954). The calculated lean body mass (body weight minus fat) has been found to be highly correlated with heat production (Miller and Blythe, 1952, 1953; Gopalan *et al.*, 1955).

Most of these data on body composition in relation to heat production were obtained from investigations on adult men. The only known one on children was by Garn *et al.* (1953). They used radiographic measurements to determine muscle size in children 6 to 18 years of age. From several tissue measurements they reported that the measurement of leg musculature provided a “good indication of the metabolically active mass,” and was highly correlated with oxygen consumption. However, the correlation coefficients were of approximately the same magnitude (0.82 for boys and 0.73 for girls) as were those with weight and oxygen consumption (0.84 for boys and 0.68 for girls) and body surface and oxygen consumption (0.83 for boys and 0.65 for girls).

Although these recent methods of indicating body composition may prove to be better reference bases for predicting basal heat production, they are impractical for extensive use and, owing to the paucity of these data on children, they will not be considered in this study.

IV.—Sources of Data and Characterization of Children

All known available data published and unpublished on the basal metabolism of individual healthy, white children in the United States have been brought together for this report. Analysis of the data was made for girls from 2 to 16 years of age and for boys 2 to 18 years. If data for older ages were included with a block of data for younger children, they have been included for comparative purposes only, and no attempt has been made to collect data for these older ages. Unpublished data have been denoted by "n.p." (not published) in place of the date of publication in Literature References, page 79.

In table 2 are given the investigators furnishing data for this integration (in the order of States as used by the Bureau of Census), with a brief description of the procedures used and other information pertinent to a comparative analysis. Reports in which only a few children were investigated and data obtained before 1920 have not been included. It was impossible to include the results of some investigations because the individual data were not available or because the data reported were not complete. The investigators not included are given in table 3. The number of basal metabolic measurements for each 6-month-age interval obtained from each investigator is shown in table 4.

In an attempt to avoid confusion in terminology, "measurement" is used herein to denote the reported basal metabolism of a given subject at a given age; "test" is used to denote a single determination of the rate of oxygen consumption (usually for a 6- or 8-minute period) with the closed-circuit method, or, the analysis of expired air during one test period with the open-circuit method. Thus, a basal metabolic "measurement" may be one test selected from a group of tests or an average of several tests, depending upon the procedure followed by the investigator.

As shown in table 2, there was a lack of uniformity among investigators as to what test or average of tests were used to represent a basal metabolic measurement and whether or not the subject had preliminary "training" or experience before the test. The type of apparatus used in making the measurements also differed among the investigators. These factors are to some extent interrelated; that is, the type of apparatus used may determine the degree of preliminary training necessary, and the basal metabolism obtained on children having repeated measurements

at periodic intervals (longitudinal type data) may differ from that on children having only one basal metabolic measurement (cross-sectional type data). In addition, the age range and, therefore, the weight range, of the children measured differed from location to location (*see* table 3). These variations in procedure make comparison difficult.

The data used herein are those reported by the investigators (*see* column 5 of table 2). No attempt was made to select the data. However, a few extreme values (total of 53 measurements) were omitted.¹

Longitudinal data were treated as cross-sectional data, except in sections V and VIII; thus, each child was considered another subject with each measurement repeated at an older age. The interval between measurements differed among the investigators (*see* column 5, table 2) as follows: Lamb (n.p.) in Texas made measurements at 2-month intervals; Lewis *et al.* (1937) in Colorado repeated tests at 3- or 4-month intervals; Eichorn (n.p.) in California at 4- or 6-month intervals; and Davenport *et al.* (1939) in New York City, at yearly intervals.

The measurements as reported by the investigators were used and no measurements on the same subject were combined, except those from Hoobler (n.p.) in Michigan. Her tests often were made several times each month for as long as 3 years on some children and, in order that they might be comparable with other subjects not tested at such frequent intervals, the data were averaged by calendar months and then by season (*see* footnote 3 in table 2).

It was obvious that there were marked differences in the average heights and weights of children for a given age reported by the various

¹ Omitted values included the following: Unreasonably high values for 1 Arizona girl (Thompson, n.p.) and 2 Chicago boys (Morse, n.p.) having only 1 test each; the first measurements on 5 girls and 10 boys reported by Webster *et al.* (1941), which were high when compared with measurements made 4 or 6 months later; 10 measurements on 1 California boy (Eichorn, n.p.), since it was recorded that he was very restless and that on several days before the test he had arisen early (between 4 and 4:30 a.m.) for a paper route and usually ate something at that time; all 11 measurements on a California girl (Eichorn, n.p.), because they were unreasonably low in relation to age, weight, and surface area; and 14 measurements from other California subjects, as they were out-of-line when compared with measurements obtained at other ages.

TABLE 2.—*Sources of data, and apparatus and procedure used for obtaining basal metabolic data*

Location	Investigator(s) ¹	Date of study	Type of apparatus	Values used to report a basal ² metabolic measurement	Selection of children	
					Age range in years	Other information
Northeast Region: Massachusetts, Boston.	Talbot, Wilson, and Worcester (1937).	1932	Closed-circuit (Benedict Portable).	Average of all tests checking within 5% of those of another period.	10 to 17--	Good economic and social surroundings. Girls were within +20% and -10% of normal by Baldwin-Wood height-weight standard. For girls only.
New York City---	Taylor (n.p.)-----	1921-53	Closed-circuit (Benedict-Roth or similar machine).	Average of at least 3 tests within 5% of lowest value (duplicate tests made on at least 2 mornings after becoming accustomed to apparatus on a preceding day). For a few subjects, tests were repeated at 6-month intervals for a period up to 6 years. Lowest test from at least 4 tests. In 1932 measurements were made at intervals of 6 to 12 months for 4 years.	3 to 20---	Subjects classified into 3 economic levels according to type of school attended.
Do-----	Topper and Mulier (1929a, 1929b, 1932).	1926-31	Closed-circuit (Krogh or Benedict-Roth).	Lowest test from duplicate tests made on 2 consecutive mornings. Yearly measurements were made over a period of from 5 to 7 years.	6 to 16---	Assumed to be in moderate income level.
New York (near N.Y.C.).	Davenport, Renfro, and Hallock (1939).	1931-37	Closed-circuit (Sanborn Graphic).	Average of 2 tests on the same morning. "If these were in disagreement, the test was repeated until check observations were obtained". Measurements were made at about 4-month intervals for a 6-year period.	8 to 18---	Patients from an institution for feeble-minded, of fair intelligence, and free from neurological symptoms.
Do-----	Webster, Harrington, and Wright (1941).	1934-39	Closed-circuit (Benedict-Roth).	A minimum agreement of 4 mm. between the oxygen consumption from at least 2 tests on same morning was required. If not achieved, subject was re-examined another day.	10 to 17--	Privately endowed institution in a rural district; distinct racial types avoided.
New York City---	Bruch (1939a, 1939b, 1942).	1939	Closed-circuit (Benedict-Roth).	Average of the lowest values for which a satisfactory check (within 5%) was obtained on 2 or more successive days. (Preliminary tests were usually made.) Average of 2 lowest results from tests made on consecutive days.	4½ to 13--	Investigation concerned with obese children.
North Central Region: Ohio, Columbus---	McKay (1930)-----	<1926-27	Closed-circuit (Benedict-Roth).		14 to 22--	College students and girl scouts (younger girls) in good physical condition. For girls only.
Do-----	Orner (1935)-----	<1935	Closed-circuit (Sanborn Graphic).		14 to 21--	Subjects were under observation at the Bureau of Juvenile Research.

Illinois, Chicago; and Ohio, Cincinnati.	Wang (1934, 1939); Wang <i>et al.</i> (1926, 1936).	1926-36	Closed-circuit (Benedict's cot chamber) and open-circuit (Tissot gasom- eter).	Average of 2 lowest tests (which varied not more than 4%) from duplicate tests on 3 consecutive days. Subjects had preliminary training tests.	4 to 20----	Majority of subjects were considered to be under- nourished. Mostly girls.
Illinois, Chicago----	Morse (n.p.)-----	<1948	Closed-circuit (San- born Graphic) and open-circuit (Douglas bag).	Average of triplicate tests made on the same morning (sometimes only 1 or 2 tests).	6 to 19----	Majority in lower middle or upper low economic status.
Michigan, Detroit	Maroney and Johnston (1937).	1933-34	Open-circuit (Tissot gasometer).	Not reported-----	5 to 13----	Subjects were hospitalized as reactors to tuberculin whose homes had been broken up because of disease in parents, but no subject included showed any active dis- ease.
Do-----	Hoobler (n.p.)--	1935-42	Closed-circuit (Benedict-Roth).	Average of duplicate tests made on the same morning; or an average of duplicate tests made on 2 or more mornings; or an average of 2 or 3 monthly averages. ³	5 to 18----	Wards of Methodist Children's Village. Mostly girls.
Kansas, Man- hattan.	Harrison (n.p.)----	1939-42	Closed-circuit (Benedict-Roth).	Average of 4 tests—duplicate tests on 2 mornings.	10 to 17--	For girls only.
Southern Region: Texas, Lubbock----	Lamb (n.p.)-----	1939-49	Closed-circuit (Col- lins-Benedict- Roth).	Average of all tests within 5% of lowest. Minimum of 2 tests on 2 mornings made on trained subjects. Measurements were repeated at intervals of 2 months or more.	2 to 7----	Random selection from applicants to Nursery School of the Depart- ment of Child Develop- ment, Division of Home Economics, Texas Tech- nological College.
Western Region: Colorado, Denver	Lewis, Kinsman, and Hiff (1937); Duval (1942).	1932-42	Open-circuit cham- ber.	One satisfactory test after a train- ing period for unexperienced subjects. If the subject made more than an occasional slight movement, the test was con- sidered unsatisfactory. Meas- urements were repeated at inter- vals of 3 or 4 months.	2 to 16----	"All classes except lowest stratum of society" in- cluded. From private homes in Denver and vicinity.
Arizona, Tucson----	Thompson (n.p.)--	1941-50	Closed-circuit (Bene- dict-Roth).	Average of at least 2 tests within 5% of that on a different morn- ing (duplicate tests made each morning).	12 to 24--	From Tucson public schools and University of Arizona. Mostly girls.
Washington, Pullman.	Esselbaugh (n.p.)--	1952	Closed-circuit (San- born Metabula- tor).	Average of duplicate tests on same night before test.	14 to 16--	From 2 counties, mostly urban.
California, Berke- ley.	Eichorn (n.p.)----	1933-39	Open-circuit with mask (Tissot gas- ometer).	Average of 3 8-minute tests made on 2 consecutive mornings after 2 trial tests on a previous day. Measurements were repeated at intervals of 4 to 6 months for a 6-year period.	9 to 18----	From 5 elementary schools; based on willingness of parents to cooperate and permanent residence in community.

¹ For Literature References, see section XI. "n.p." denotes not published.
² Subjects were awake and in post-absorptive condition; testing was pre-
ceded by a rest period.

³ About one-third of the subjects (total of 79) were tested on only 1 morning;
the other subjects were tested once or several times (on as many as 6 mornings)
each month for a period ranging from 2 to 36 months. All tests made within
a given calendar month were averaged; these monthly averages, in turn,

were averaged by season (3-month periods as follows: Jan., Feb., and March;
April, May, and June; July, Aug., and Sept.; Oct., Nov., and Dec.). Thus,
the "basal" values used for a given subject at a given age may be an average
of values obtained during 1, 2, or 3 months; and each monthly average may
be based on duplicate tests on 1 morning (approximately half of the values
reported) or on 6 mornings.

TABLE 3.—*Published data on basal metabolism of children not included in this publication*

Location	Investigator(s) ¹	Date of study	Type of apparatus	Values used to report a basal metabolic measurement	Age range in years	Reason for omission
Northeast Region: Massachusetts, Boston.	Benedict and Talbot (1921).	1913-19	Closed-circuit (Respiration chamber).	Lowest value obtained (but confirmed by a test on another day) from measurements divided into periods of 20 or 30 minutes, with the number of periods depending upon degree of repose of subjects. Younger children were measured after feeding and were usually asleep; older children were often asleep during the test period.	Birth to 14.	Many of the children were asleep when measured; therefore, are not comparable to more recent data measured when children were awake.
New York City.	Lewis, C. A. (1936)-----	1932-33	Closed-circuit (Benedict-Roth with helmet).	Average of 2 lowest tests made on different days and which agreed within 5% of each other.	14 to 16-----	Individual data not reported. For girls only.
New Jersey, Jamesburg.	Molitch and Cousins (1934).	<1934	Closed-circuit (Santborn Graphic).	Consecutive tests were made every 24 hours until not more than a 4% difference was obtained; those tests which checked were then averaged.	12 to 16-----	Data for individual subjects were not available. For boys only.
North Central Region: Ohio (Southwestern).	Garn and Clark (1953).	1945-52	Closed-circuit (Jones-Basal).	Average of 2 tests—other than trial test.	6 to 18-----	Data for individual subjects were not available. For boys only.
Illinois, Chicago.	Blunt <i>et al.</i> (1926); Gunn (1925); Tilt (1923).	1922-25	Closed-circuit (Benedict Portable or Benedict-Roth).	If duplicate tests on 2 subsequent days agreed within 5%, average value reported; otherwise the 2 lowest values of the 2 days used if these checked.	8 to 18-----	Not in post-absorptive condition as had eaten a light breakfast previous to test.
Michigan, Coldwater.	Rothbart (1935)-----	1932-33	Closed-circuit (Benedict-Roth).	Lowest test from duplicate readings made on subsequent days until it was felt that basal conditions were obtained.	9 to 16-----	Height and weight of subjects not reported.

Southern Region: Oklahoma, Stillwater.	Nalbandov <i>et al.</i> (1938) and Krause (1936).	1935-36	Closed-circuit (Benedict-Roth).	Average of duplicate tests	3 to 16	Apparently some error in table headings. Data reported are contradictory to those from other investigators, i.e., Cal./sq. m./hr. increased with increasing age. Values were unavail- able when computa- tions were made.
Louisiana, Tennessee, and Virginia.	Technical Committee of the Southern Regional Nutrition Research Project (S-28).	1954-58	Closed-circuit (Benedict-Roth or McKesson).	Average of 2 tests on the same day after at least 1 pre- liminary "test" prior to actual determination.	6½ to 10	
Western Region: California, San Francisco.	Lucas and Pryor (1933); Lucas, Pryor <i>et al.</i> (1932, 1933).	<1932-33	Closed-circuit (Benedict-Roth).	Average of 2 consecutive tests that checked.	3 to 18	Data reported as per- centage deviation from Benedict- Talbot standard.

¹ For Literature References, see section XI.

TABLE 4.—Number of basal metabolic measurements on

Location	Investigator(s) ¹	2 years	2½ years	3 years	3½ years	4 years	4½ years	5 years	5½ years	6 years	6½ years	7 years
Boys												
Northeast Region:												
New York City	Taylor (n.p.)			1	5	4	1	1	0	1	1	1
Do	Topper and Mulier (1929a, 1929b, 1932).									6	0	4
New York	Davenport <i>et al.</i> (1939)											
Do	Webster <i>et al.</i> (1941)											
New York City	Bruch (1939a, 1939b, 1942)								2	1	2	2
North Central Region:												
Ohio	Orner (1935)											
Illinois & Ohio	Wang (1934, 1939); Wang <i>et al.</i> (1926, 1936).							2	0	3	0	2
Illinois	Morse (n.p.)										2	0
Michigan	Maroney and Johnston (1937)								2	2	0	1
Do	Hoobler (n.p.)						1	2	1	2	1	3
Southern Region:												
Texas	Lamb (n.p.)			2	9	12	5	7	5	4	0	2
Western Region:												
Colorado	Lewis <i>et al.</i> (1937); Duval (1942).	13	34	41	42	46	41	49	54	54	50	49
Arizona	Thompson (n.p.)											
Washington	Esselbaugh (n.p.)											
California	Eichorn (n.p.)											
Total, all locations		13	34	44	56	62	48	61	64	73	56	64
Girls												
Northeast Region:												
Massachusetts	Talbot <i>et al.</i> (1937)											
New York City	Taylor (n.p.)			3	6	4	1	1	0	2	1	0
Do	Topper and Mulier (1929a, 1929b, 1932).							1	0	5	0	1
New York	Davenport <i>et al.</i> (1939)											
Do	Webster <i>et al.</i> (1941)											
New York City	Bruch (1939a, 1939b, 1942)						1	1	0	1	2	3
North Central Region:												
Ohio	McKay (1930)											
Illinois and Ohio	Wang (1934, 1939); Wang <i>et al.</i> (1926, 1936).					4	0	2	0	5	0	2
Illinois	Morse (n.p.)									1	2	1
Michigan	Maroney and Johnston (1937)								1	0	0	0
Do	Hoobler (n.p.)								4	4	4	1
Kansas	Harrison (n.p.)											
Southern Region:												
Texas	Lamb (n.p.)		3	2	7	9	7	4	2	1	1	2
Western Region:												
Colorado	Lewis <i>et al.</i> (1937); Duval (1942).	24	36	36	35	44	35	42	44	39	42	33
Arizona	Thompson (n.p.)											
Washington	Esselbaugh (n.p.)											
California	Eichorn (n.p.)									1	0	1
Total, all locations		24	39	41	48	61	44	51	51	59	52	44

¹ For Literature References, see section XI.

children, 2 to 18 years of age, from each investigator

7½ years	8 years	8½ years	9 years	9½ years	10 years	10½ years	11 years	11½ years	12 years	12½ years	13 years	13½ years	14 years	14½ years	15 years	15½ years	16 years	16½ years	17 years	17½ years	18 and over	Total
Boys—Continued																						
4 0	2 2	4 0	8 9	26 0	27 12	19 0	19 9	20 1	27 17	8 5	3 10	6 10	3 9	4 5	3 4	4 3	3 1	1 1	1	0	1	208 108
-----	1	0	5	0	11	0	25	1	36	3	42	0	41	0	36	0	29	0	18	0	7	255 115
2	2	0	2	3	3	3	4	7	12	14	10	13	11	11	11	10	7	3	2	-----	-----	37
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1	0	7	2	3	4	1	0	3	21 15
0	1	0	0	0	5	0	1	0	0	0	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1 0 4	1 0 4	1 0 6	0 0 7	3 3 3	1 4 0	1 0 2	5 1 2	10 3 0	5 0 3	12 1 1	9	9	16	13	9	9	10	8	4	0	1	130 17 42
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1	-----	-----	-----	-----	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1	-----	-----	-----	-----	-----	49
45	54	53	42	48	38	40	32	27	23	28	24	16	19	17	10	11	1	-----	-----	-----	-----	1,001
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1	4	45	50 124 552
-----	-----	-----	2	3	14	5	7	16	38	45	49	43	45	25	27	28	34	10	-----	-----	-----	-----
57	67	64	75	89	116	70	107	88	163	122	150	98	145	125	160	110	131	61	55	28	68	2,724
Girls—Continued																						
-----	-----	-----	-----	-----	-----	1	2	10	5	4	3	3	5	6	7	5	9	-----	-----	-----	-----	60 311 179
2 0	2 5	11 0	12 3	27 0	31 16	26 1	24 25	44 5	30 31	17 13	11 20	7 15	11 18	6 5	4 8	4 2	2 4	2	2	3	15	-----
1	2	1	9	0	16	0	26	1	40	3	44	1	44	0	40	0	27	0	15	0	3	273 82 39
2	2	5	3	6	1	3	4	5	6	11	8	8	7	9	6	5	3	2	1	-----	-----	-----
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
0	6	0	4	0	6	2	3	1	6	5	3	2	3	7	9	9	10	5	14	25	12	96 67
1 1 0	4 1 0	1 4 2	1 1 1	1 2 2	1 3 3	1 3 1	3 1 5	5 1 3	2 0 5	3 1 7	7 11	4 14	1 14	1 19	2 26	3 20	-----	-----	-----	-----	2	47 19 219
-----	-----	-----	-----	-----	18	5	15	6	9	5	9	5	10	6	8	4	21	15	6	-----	-----	142
-----	-----	-----	-----	-----	-----	-----	-----	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	39
39	33	33	23	22	22	22	13	14	13	11	15	13	7	8	8	5	2	-----	-----	-----	-----	713
-----	-----	-----	-----	-----	-----	-----	-----	-----	5	13	11	16	18	28	19	20	9	20	17	17	162	355 119 526
0	1	0	2	2	13	6	6	18	37	51	47	50	50	45	41	33	35	32	28	20	7	-----
46	56	57	59	62	133	75	128	117	192	144	189	141	192	164	217	137	179	100	101	74	209	3,286

BOYS

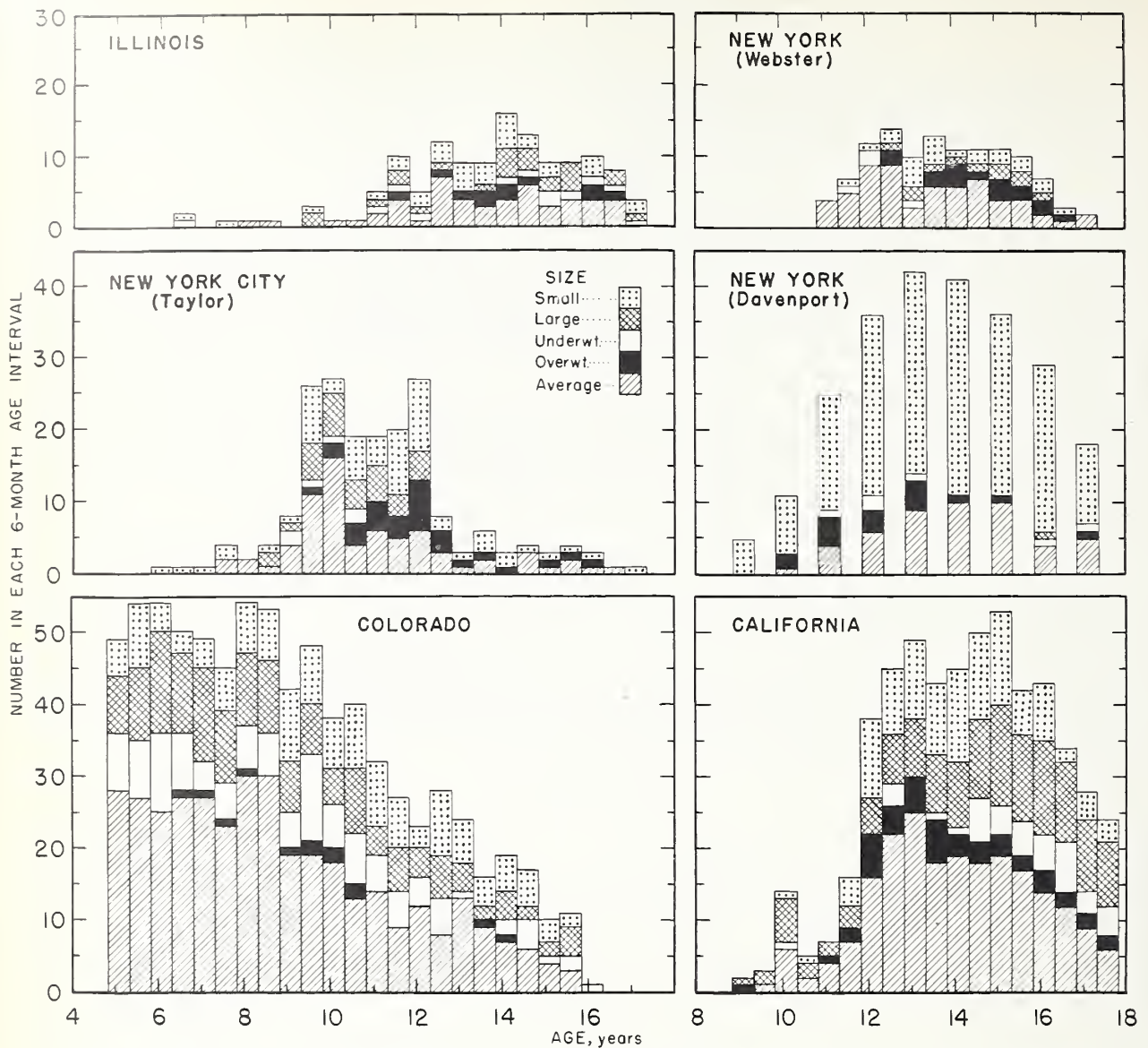


FIGURE 2.—Distribution of boys and girls into five height-weight-age divisions (sizes) for each of six locations.

Data for New York City, from Taylor (n.p.) ; for New York, from Davenport, Renfro, and Hallock (1939) and Webster, Harrington, and Wright (1941) ; for Illinois, from Morse (n.p.) ; for Michigan, from Hoobler (n.p.) ; for Colorado, from Lewis, Kinsman, and Iliff (1937) and Duval (1942) ; for Arizona, from Thompson (n.p.) ; for California, from Eichorn (n.p.).

investigators. To illustrate, three investigators within the same locality (New York) reported the average height of girls 10 to 16 years of age to be as follows:

Age, years	Davenport <i>et al.</i> (1939) Cm.	Webster <i>et al.</i> (1941) Cm.	Taylor (n.p.) Cm.
10-----	130. 1	133. 5	138. 2
11-----	135. 2	142. 6	142. 7
12-----	140. 3	147. 8	150. 9
13-----	146. 1	152. 3	156. 2
14-----	150. 8	155. 9	159. 4
15-----	153. 2	156. 4	164. 1
16-----	155. 0	159. 2	169. 8

The foregoing values show that the girls measured by Davenport *et al.* (1939) were shorter and those measured by Taylor (n.p.) were taller than the girls measured by Webster *et al.* (1941). The differences in physical size among the boys from these three locations were similar to those found for the girls.

Thus, in order to have groups of children more homogeneous in size for comparison of the heat-production data reported from all investigators, the data for children 5 to 18 years were separated into five height-weight-age divisions: "average"

GIRLS

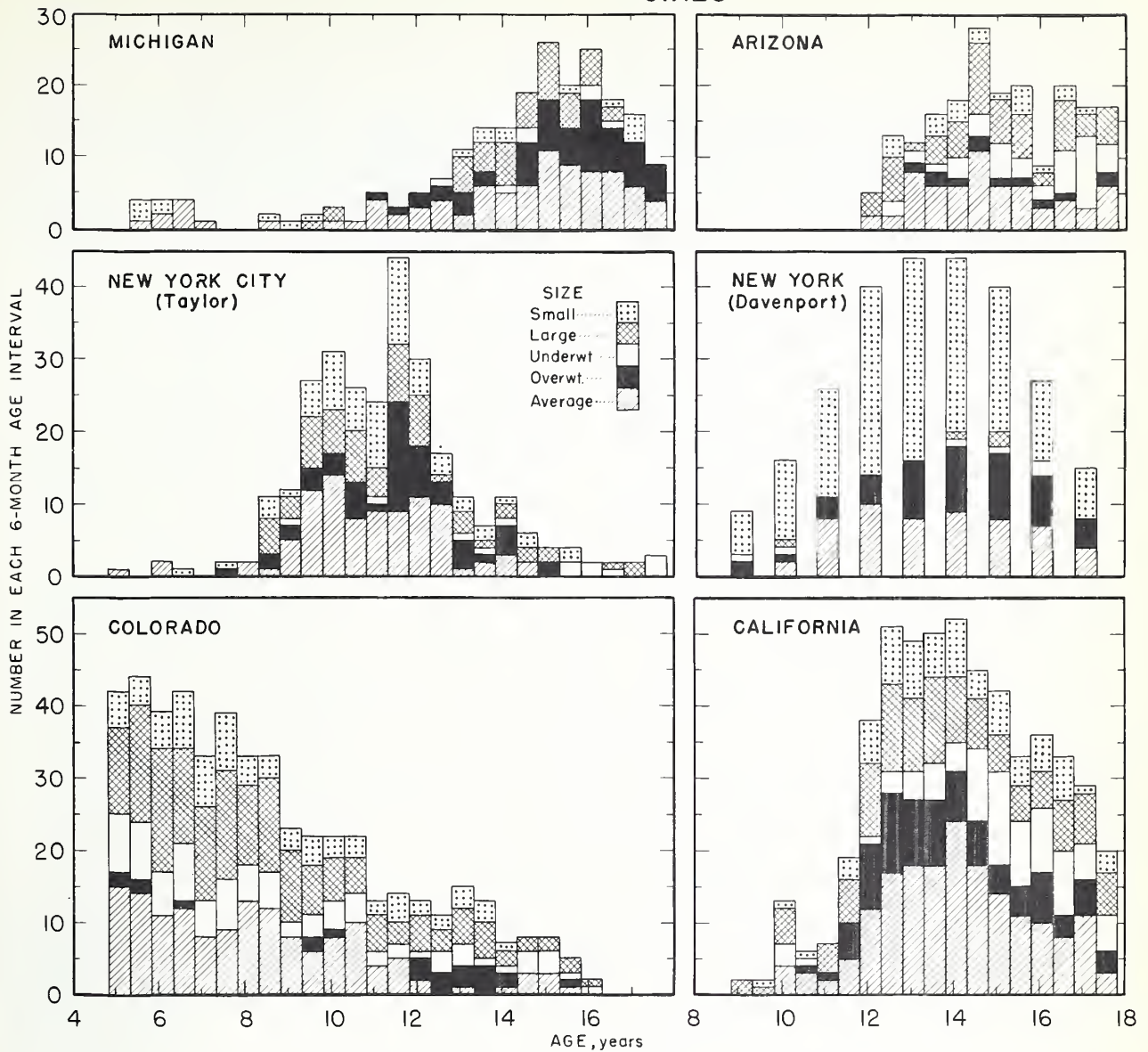


FIGURE 2.—Continued

height and weight for age, “large” or “small” for age (but well-proportioned), “overweight” and “underweight” (weight out-of-proportion to height). These divisions were based on the Stuart-Meredith (1946) height-weight standards; further details are given in appendix A.

A comparison of the distribution of the children into these height-weight-age divisions from the various sources (figure 2) illustrates further what was shown for children from New York—that there are marked differences in height and

weight of children studied by the various investigators. For example, as shown in figure 2 (right chart) nearly as many of the Colorado girls (Lewis *et al.*, 1937; Duval, 1942) were in the large as in the average division and more children were underweight than overweight. In contrast, more than half of the children measured by Davenport *et al.* (1939) were in the small for age division. A comparison of data for boys and girls indicates also that there were more measurements on overweight girls than there were on overweight boys.

These differences in the distribution of the children may be attributed, in part, to the background of the children measured (*see* last column of table 2). Analysis of supplemental data from three sources giving data on their economic background indicated that the percentages of children in the small and in the overweight divisions were higher from groups reflecting a low than a higher economic level. The details of the analysis of these data according to economic background are presented in appendix A.

A preliminary analysis of the basal heat-production data was made for the height-weight-age divisions according to the tradition initiated by Aub and Du Bois (1917)—that is, in terms of Calories per unit of body surface for a given age. Since heat production per unit of body surface was higher for small children and lower for large children than for children of average height and weight for age, it was concluded that surface area related to *age* does not correct for differences in body size of children. The details of this analysis also are presented in appendix A.

V.—Analysis of Age Curves From Longitudinal Data for Determining Inflections in Heat Production

Age is not considered a reliable reference base to use for basal metabolism because of the variations in growth rate, especially during the adolescent period, and also because of the wide range in the age at which physiological maturity is reached. Nevertheless, the changes associated with age are important and cannot be ignored; thus, the measurements obtained at repeated intervals of several months on the same individual throughout the growth period are valuable for studying the metabolic changes associated with age.

Longitudinal data from several investigators were available for a period of 6 to 9 years, but none represented for a given group of subjects the entire growth period, that is, from 2 years of age to physiological maturity. Within an investigation, however, the entire age span may be represented by longitudinal data, although not on the same children; for example, the data for some children covered the age span from 2 years to 9 years (figure 3) and data for other children, from 7 years to 16 years (figure 4).

When the measurements for the same individ-

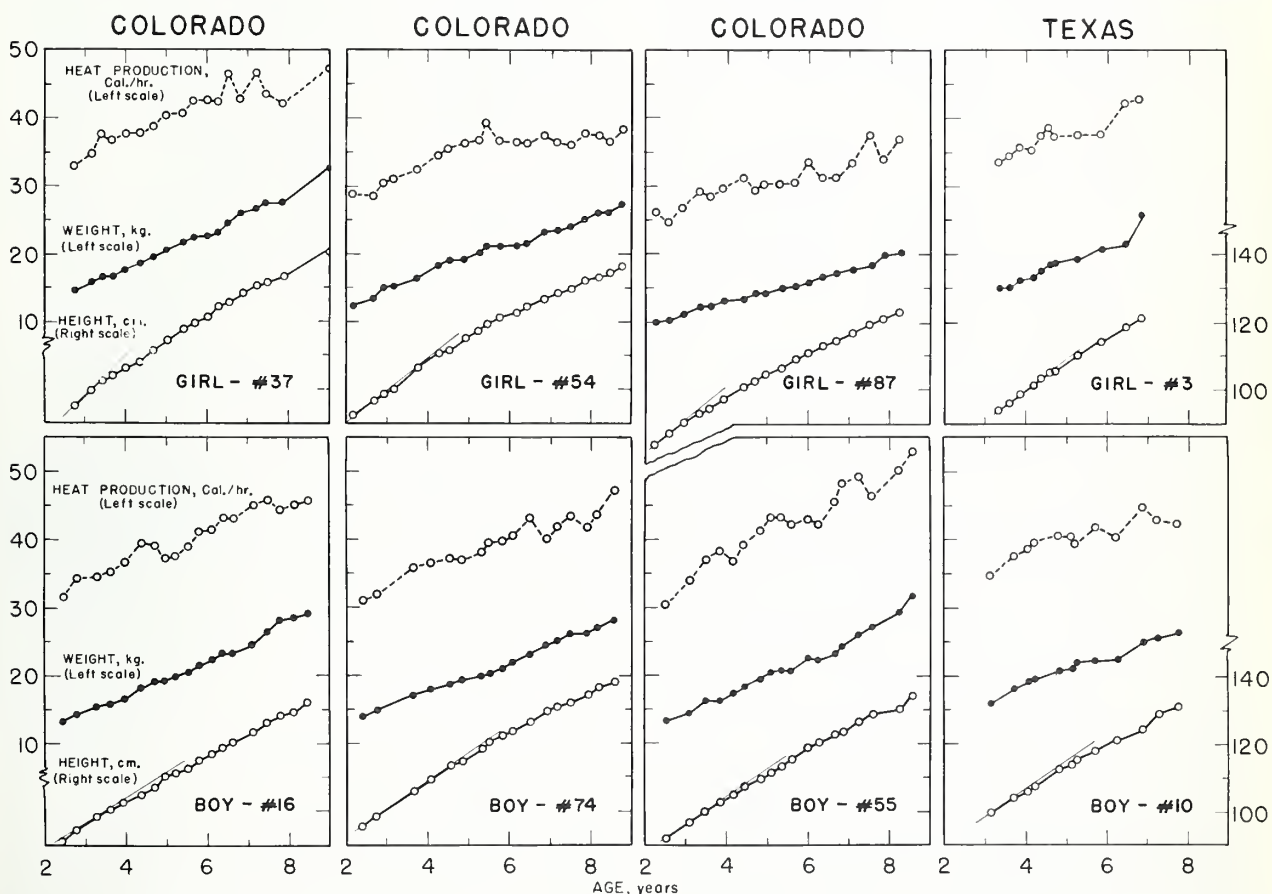


FIGURE 3.—COLORADO AND TEXAS CHILDREN 2 TO 9 YEARS OLD: Longitudinal data for height, weight, and basal heat production (Cal./hr.).

Light lines are drawn through the height curves at the younger ages to aid in detecting the change in growth rate. Data for Colorado children, from Lewis, Kinsman, and Iliff (1937) and Duval (1942); for Texas children, from Lamb (n.p.).

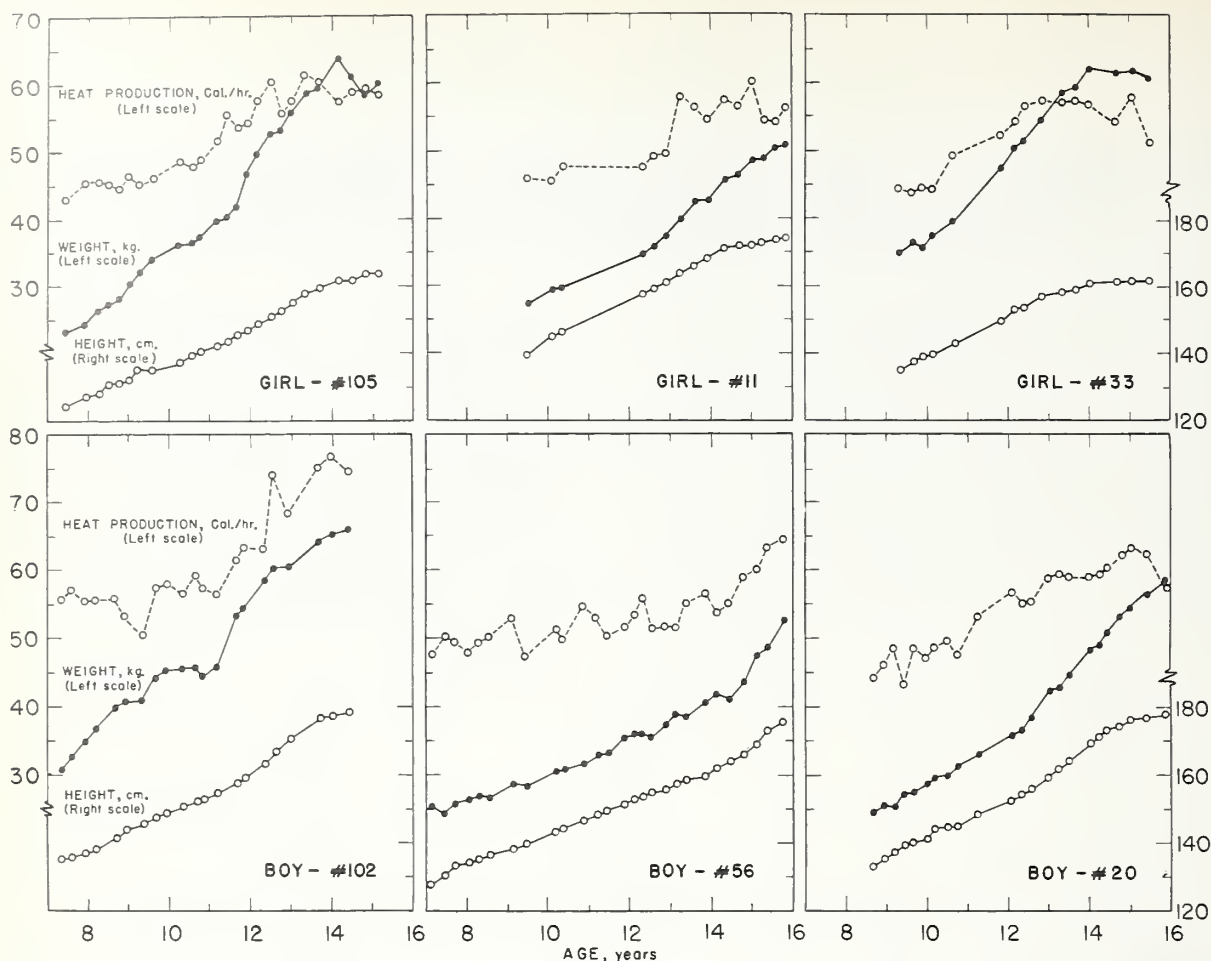


FIGURE 4.—COLORADO CHILDREN 7 TO 16 YEARS OLD: Longitudinal data for height, weight, and basal heat production (Cal./hr.).

Data from Lewis, Kinsman, and Iliff (1937) and Duval (1942).

ual extended over a period of 4 or 5 years, the basal heat-production curves were plotted, examined carefully, and compared with the corresponding age curves for height and weight. It would be impossible to show all the age curves in this publication, but a few have been selected which illustrate that the rate of basal metabolism changes between 4 and 5 years of age and again at puberty. These breaks correspond to the inflections in the age curve of growth.

Height in relation to age was used as a criterion to indicate the change in growth rate, as it is a better measure of growth than weight (*see* Adams and Poulton, 1937). Nylin (1929) reported that the increase in height had more effect on heat production than gain in weight from periodic observations made on eight children 5 to 6 years of age. Davenport *et al.* (1939) found that the changes in basal metabolic rate "probably slightly precedes the spurt of growth in stature" from yearly observations made before, during, and after the prepubertal growth spurt.

The age curves in figure 3 illustrate that height increases at about the same rate from 2 years up to 4 or 5 years and thereafter increases at a slower rate. At this age there is a corresponding change in basal heat production and usually a similar change in weight. In the longitudinal data on Colorado children (Lewis *et al.*, 1937; Duval, 1942), the age span for 24 girls and 26 boys was of sufficient length to determine the age at which the change in the rate of increase in height occurred. If the "break" was not clear-cut with arithmetic coordinates, semilogarithmic coordinates were used to detect this change. This break occurred at about 4 years of age for girls (average weight 18 kilograms) and 4½ years for boys (average weight 20 kilograms). On the basis of longitudinal data on 3 boys and 3 girls reported by Lamb (n.p.), Texas children showed breaks at these same ages.

After the change in growth rate at about 4 or 5 years of age, growth in height increased at about the same rate for a given individual up to

about 12 years, when a sudden spurt in growth usually occurred (*see* figure 4). The age at which this growth spurt began varied greatly for individual children and occurred earlier in girls than in boys; in some children the increase was much more pronounced than in others. Basal heat production showed a corresponding increase during the growth spurt; however, the rate of increase paralleled that in weight (for example, *see* subject Nos. 56, 102, and 105 in figure 4, and No. 80 in figure 5).

Heat production began to level off, or even declined, at about the time the maximum growth rate in height was reached (*see* figure 5). In girls this coincided with the onset of menarche (or puberty). The onset of menarche for the girls shown in figure 5 varied from 12 to 14½ years, but for each girl it was associated with a decline in growth of height and a corresponding decline, or leveling off, in heat production. That the onset of menarche is related to the cessation of the growth in height has been reported by Nylin (1935), and that basal metabolism decreases with beginning of menarche has been reported by Shock (1943).

In boys the decline in the rate of heat produc-

tion also coincided with the change in the rate of growth in height (figure 5) as physiological maturity was approached. For this publication the age at which this change occurred will be designated as the age of "puberty" in the boys to correspond to the age of onset of menarche in the girls.

After puberty (onset of menarche in girls) heat production was usually more variable in a given child as well as among children: In some children a definite decline was noted (*see* Nos. 47, 65, figure 5); in some it was more or less constant (*see* Nos. 137, 172, figure 5); whereas in others an increase was evident but the rate was slower than previously (*see* No. 157, figure 5). The heat-production curves paralleled the corresponding weight curves; thus, those curves that showed a decline in heat production also showed a constancy in weight during this period; in those that showed no change in heat production, weight increased slightly; in those that showed an increase, weight showed a decided increase. If weight increased for a period of a year or more and then declined, as in No. 80, figure 5, heat production showed a corresponding trend.

That there is an increase in basal metabolism

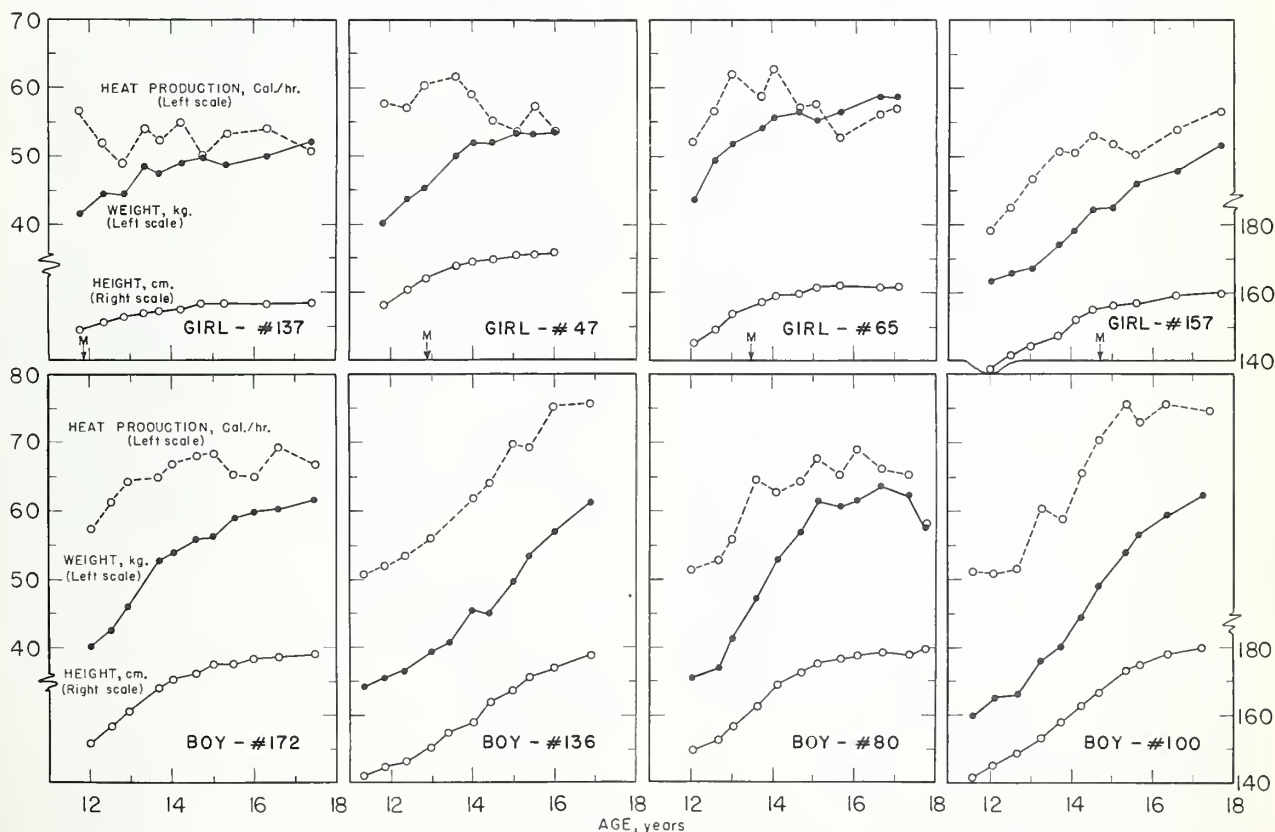


FIGURE 5.—CALIFORNIA CHILDREN 11 TO 18 YEARS OLD: Longitudinal data for height, weight, and basal heat production (Cal./hr.).

Note that heat production increases with increasing weight and height during the prepubertal period but at onset of menarche (indicated by "M" at arrow), or when maximum growth rate in height is reached, heat production levels off or declines. Data from Eichorn (n.p.).

associated with puberty has been reported by many investigators. Aub and Du Bois (1917) indicated an increase in metabolism (Calories per square meter) for boys 12 to 15 years of age. Topper and Mulier (1932) concluded from measurements made at intervals of 6 months to a year on boys and girls 10 to 16 years old that the basal metabolic rate was increased before puberty, reached its maximum about the time the menarche was established in girls and sexual maturity in boys, and declined thereafter. They believed that "this increase coincides with the physiologic age rather than with the chronological age, and occurs earlier in girls than in boys, coincident with their earlier pubescence."

Eichorn (1955) demonstrated that the decline in basal heat production in girls at ages over 14 years was related to physiological maturity; by plotting heat production against age deviation from menarche, a curvilinear relationship was demonstrated in which heat production increased to the menarche and decreased thereafter.

Although the results from the above investigations present ample evidence that the basal heat production decreases following onset of menarche or sexual maturity, no standards for prepubertal children as contrasted with postpubertal are available. However, Vogelius (1945) divided his basal metabolic data into two age groups, since the data for the 16- to 18-year old girls were found to "deviate significantly from those for the 7- to 15-year old" girls. Consequently, a standard was constructed for the 7- to 15-year old girls, but the data were insufficient for constructing a standard for the older group of girls.

There have been reports in which an increase in metabolism associated with puberty was not evident. Benedict and Talbot (1921) concluded that puberty had no effect on basal heat production, although they reported that a high heat production at puberty compared with a measurement made before puberty was found on one girl; the associated increase in body weight during this period was offered as the explanation. Measurements made by Benedict and Talbot (1921) during the adolescent period were comparatively few and were of the cross-sectional type, whereas longitudinal data on individual children showing the rate of basal heat production before, during, and after the prepubertal growth spurt are necessary to show the changes associated with puberty. Likewise, Biering (1931) found no evidence of an increase in the *average* relative heat production of boys, although there were individual increases in a group of 14- and 15-year old boys.

On the basis of longitudinal observations during adolescence, Webster *et al.* (1941) reported that "no evidence of an increase in the average relative heat production at the time of so-called 'puberty' was found." Measurements on many of these children were not begun until 12 years of

age. Therefore, any increase would be less obvious than when data for preceding ages were available for comparison. However, an examination of the age curves for their individual children showed an increase in heat production during the prepubertal growth spurt. The average curve for the boys also showed a slight increase in heat production per unit of body surface between 13 and 16 years. Therefore, we consider their results to be in agreement with those from other workers reporting an increase in metabolism during puberty.

In a more recent analysis of basal metabolic data Quenouille *et al.* (1951) also reported that there was "no evidence of any significant change in basal metabolism at, or about, puberty."

The controversy regarding this increase may be explained by the methods used in interpreting the results as indicated by Nylin's (1935) conclusions from observations on 12 girls during a 4-year period. He reported that: "During this maximum (the accentuated height-growth period) the standard metabolism, taken absolutely, increases considerably. Calculated per square meter of body surface or per kilogram of body weight, the standard metabolism is either increased or constant during the maximum intensity of height-growth, which affords strong evidence for the assumption that during this period an increase in combustion takes place in the organism."

Thus, if heat production is shown in relation to weight, the increase should not be apparent, as both heat production and weight are increasing at about the same rate. In averaging groups of data for a given age, the results may not show an increase, as some subjects may be showing a rise while others a fall, depending upon the age at which physiological maturity is reached. This distortion is illustrated by comparing the heat production and weight curves for three girls (Nos. 47, 137, and 157) in figure 5.

In subject 137 the level of heat production was variable but changed very little after 12 years (onset of menarche); in subject 47 heat production declined decidedly 1 year after the onset of menarche; in subject 157 it dropped slightly at about 15 years (onset of menarche), followed by a rise corresponding to an increase in weight. Thus, the average heat production of these three subjects would not be representative of the true picture showing the changes associated with the prepubertal growth spurt, because all matured at different ages.

When heat production is expressed per unit of body surface, the change associated with the prepubertal growth spurt is not so pronounced and is often overlooked, since height and weight likewise increase during this period. Therefore, heat production per unit of body surface declines with advancing age and the increase during the prepubertal growth spurt may not be large

enough to show a definite increase per unit of body surface. Instead, it may be indicated by a "leveling off" or a change in the *rate* of decline.

From the foregoing analysis of the longitudinal data, it is concluded that changes in the basal metabolic *rate* occur between 4 and 5 years of age and at about puberty. (The increase during the prepubertal growth spurt coincides with an increase in weight, so that the increase in heat production per unit increase in weight is unchanged during this period of rapid growth.) After puberty the variability in metabolism is much greater and probably reflects the physiological adjustments necessary to change from the higher metabolic rate of a growing child to the lower metabolic rate of an adult in whom the maximum height has been reached, although weight may continue to increase.

Thus, on the basis of physiological changes the age span from 2 years to maturity may be separated into the three following age intervals: Pre-school (girls from 2 to 4 years, inclusive, and boys 2 to 4½ years, inclusive), School Age to Puberty, and Postpubertal. The third group represents a "transition period" between puberty and physiological maturity and included girls up to 16 years and boys up to 18 years of age. Data for girls 16 years and older and boys 18 years and older were included only when they were a part of a study of younger ages to indicate for comparative purposes the rate of metabolism established after maturity.

To separate the data into "School Age to Puberty" and "Postpubertal" age intervals, the age at which the growth rate in height changed (as determined by plotting height against age on semilogarithmic paper) was used to indicate the age of "puberty" for the longitudinal data, unless the age of onset of menarche for girls was reported. For the cross-sectional data, the following tabulation was set up, on the basis of results from the available longitudinal data:

	Boys ¹ Years	Girls ² Years
Stocky or Overweight: ³		
Tall for age-----	14½	12½
Average height for age-----	15	13
Short for age-----	15½	13½
Normal, Slender, or Underweight: ³		
Tall for age-----	15	13
Average height for age-----	15½	13½
Short for age-----	16	14

¹ Represents the average age at which the increase in height declines as physiological maturity was approached.

² Represents the average age of onset of menarche.

³ Weight-for-height classification to be described in section VI.

Exceptions to the above tabulation were made in several cases, especially for boys under 15 years of age, who were tall for their age and showed a decidedly low metabolic rate corresponding closely to the Postpubertal group. From studies on obese children, Bruch (1939a, 1939b, 1942) found that menarche sometimes occurred before 10 years of age in girls, and pubertal development sometimes was attained by boys 11 or 12 years of age.

VI.—Weight-for-Height Classification of Children

The conventional practice for indicating nutritional status and for interpreting data on children is to compare a child's height or weight in relation to his *age* with some selected height-weight standard (see appendix A). Because of the wide range in the heights and weights of children for any given age and because of the differences in growth rates, this procedure is often unsatisfactory (see Tanner, 1952), especially since successive generations of children are progressively taller and heavier and are maturing earlier.

That body weight in relation to height, disregarding age, may be a more logical means of comparison than the relationship between weight and age or height and age was pointed out as early as 1921 by Benedict and Talbot in their metabolic studies on children. These workers drew a curve through plotted values of height (Y-axis) for weight (X-axis) on an arithmetic scale to indicate the bodily proportion of their children. They considered that on the basis of *age* the taller, and therefore the heavier, private school children were superior to the laboratory children. However, when using the relationship between *height and weight* for comparison, the laboratory children were considered superior, since they weighed more for a given height. From their viewpoint excess weight was advantageous during the period of growth. Therefore, the laboratory children were considered to be better proportioned, whereas the private school children were considered to be underweight for their height.

Of the height-weight standards presented by Hathaway (1957) in the compilation, "Height and Weights of Children and Youth in the United States," only two standards show a functional relation between height and weight. The Bayer-Gray (1935) charts show on arithmetic scales the average height plotted as function of weight and indicate ranges for each year of age; the resulting curve is curvilinear. The more complicated Wetzel grid (1941) employs logarithmic² scales to present weight (Y-axis) in relation to height (X-axis) to indicate nine physique channels or six body-types; a second set of curves (the

auxodiomes) is used to show development in relation to age.

Other investigators also have used logarithmic grids to show the height-weight relation during growth. Logarithmic scales were used in the nomograph presented by Vogelius (1945) to indicate whether the "weight-height balance" was normal or abnormal for girls 7 to 15 years old (for girls older than 15 years, the weight increased out-of-proportion to their height). Brody (1945), using data of Woodbury (1921) and Hastings (1902), showed the relation of weight to height in humans from birth to 22 years on logarithmic coordinate paper and reported that "breaks" occurred at 1, 5, and 15 years of age (with corresponding heights of about 70, 110, and 140 centimeters); thus, the age span was divided into four segments, each having a different slope.

Similarly, a weight-height relation on logarithmic coordinate paper was reported by Døssing (1952) for the age span, birth to 18 years, and by Asmussen and Heebøll-Nielsen (1956) for children 7 to 16 years of age.

Døssing (1952) separated the curve into "three rectilinear sections" with "bends" occurring at 75 and 120 centimeters (corresponding to about 1 year and between 6 and 7 years of age). For the section beginning with a height of 120 centimeters, he derived logarithmic equations, $W = cH^m$, for measurements on 2,308 boys and 2,433 girls. The slope (m in the equation) of the average weight-height line was slightly steeper for the girls (2.80) than for the boys (2.64); this difference was attributed to an earlier cessation of growth in height with continued increase in weight on the part of girls. The constant (c in the equation) was found to vary for individual children and indicated the level of the growth line; a low level indicated a slender type of body and a high level, a stocky type.

Logarithmic charts for determining the level and slope of the growth rate for boys and girls of school age were constructed by Døssing (1952). The average weight-height line was used as the basis for the chart, and lines for plus and minus 1, 2, and 3 times the standard error of the average weight for height served as boundary lines for areas between the designated standard errors.

Using average (50th percentile) values from Stuart-Meredith (1946) as typical of recent height-weight standards for children in the United States, we found that weight for height

² "Logarithmic" paper as used herein denotes that both the X-axis and Y-axis are logarithmically divided and corresponds to the "double logarithmic" or "log-log" terminology sometimes used. In contrast, "semilogarithmic" paper denotes paper which has the X-axis arithmetically divided and the Y-axis logarithmically divided.

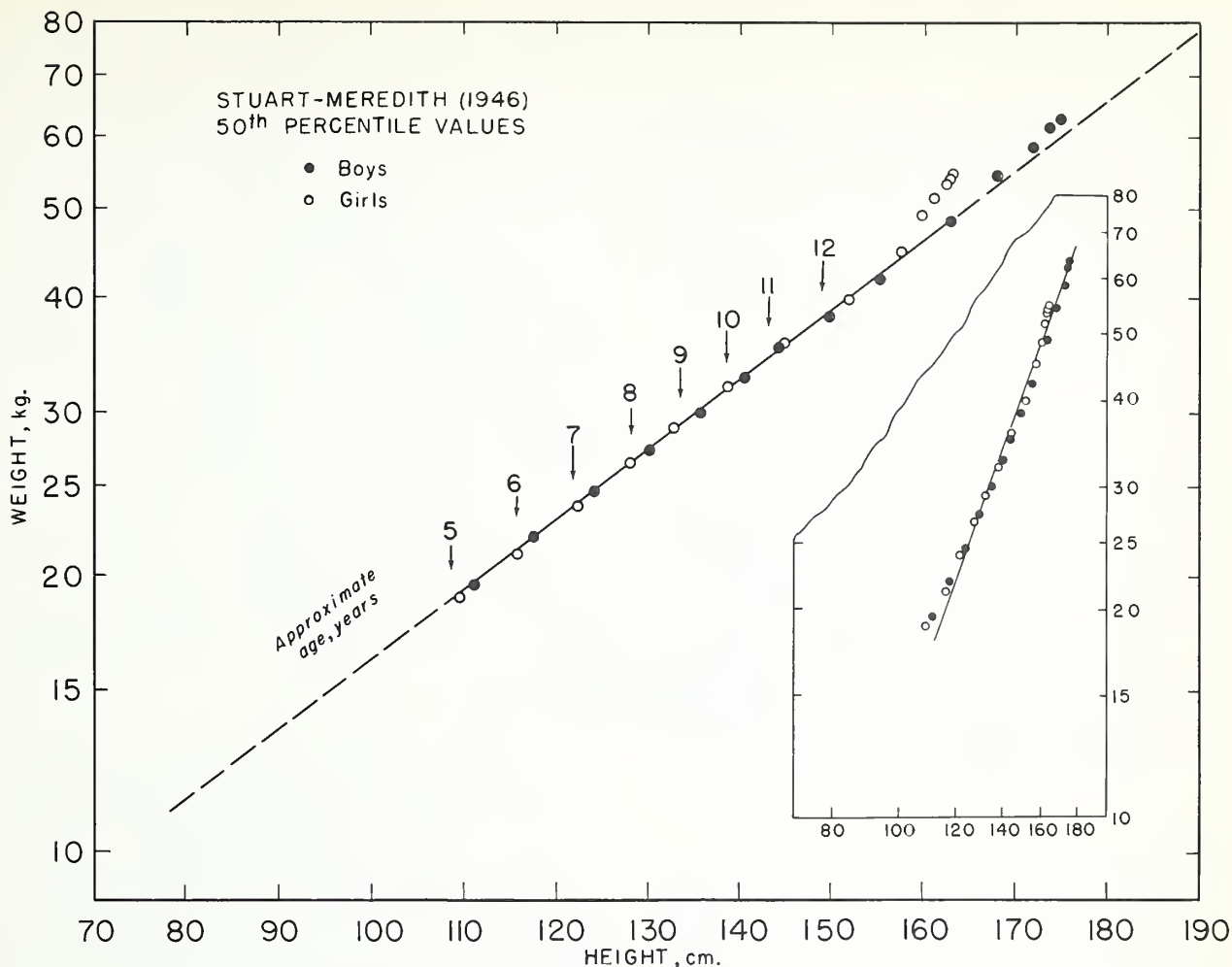


FIGURE 6.—Stuart-Meredith (1946) height-weight data plotted on a semilogarithmic grid.

The average line was fitted by "inspection." Ages corresponding to the data points are indicated. The insert shows the same data plotted on a logarithmic grid.

was satisfactorily represented on semilogarithmic paper (figure 6) by a single line for heights from 110 centimeters to about 160 centimeters for girls and to about 170 centimeters for boys, or for ages 5 to 13 years for girls and 5 to 15 years for boys.

The 50th percentile values from Boyd's Standards (1952) and average values from Bayley's data (1956) agreed well with the Stuart-Meredith Standards and justified extending the straight-line curve downward to about 75 centimeters on the basis of data for children 2 to 5 years old (figure 7). Two straight-line segments (with a break at about 120 centimeters) would be necessary to represent the same height span (75 to 160 centimeters) on logarithmic paper as shown in the insert in figure 7 and by other investigators previously mentioned (Brody, 1945; Døssing, 1952).

There was, however, a definite upward swing from the straight-line of average values for girls

13 years and older and for boys 15 years and older (about 160 and 170 centimeters height, respectively). This upward trend was more pronounced in the data from Stuart-Meredith (figure 6) and from Bayley (figure 7) than in the data from Boyd (figure 7), and was much more pronounced for girls than for boys. A similar trend was found also on the logarithmic curves (see insert in figures 6 and 7). The trend for boys and girls to become heavier in relation to height as they approach maturity may be attributed to the tendency for girls to add a greater percentage of fat and for boys to increase in muscular development (Talbot, 1925; Reynolds, 1950; Eichorn and McKee, 1953; Garn and Clark, 1953; Hammond, 1955; Asmussen and Heebøll-Nielsen, 1956).

The more pronounced change in the relationship between weight and height at about the time of puberty for girls may be associated in part to the difference in bodily proportions of boys and girls.

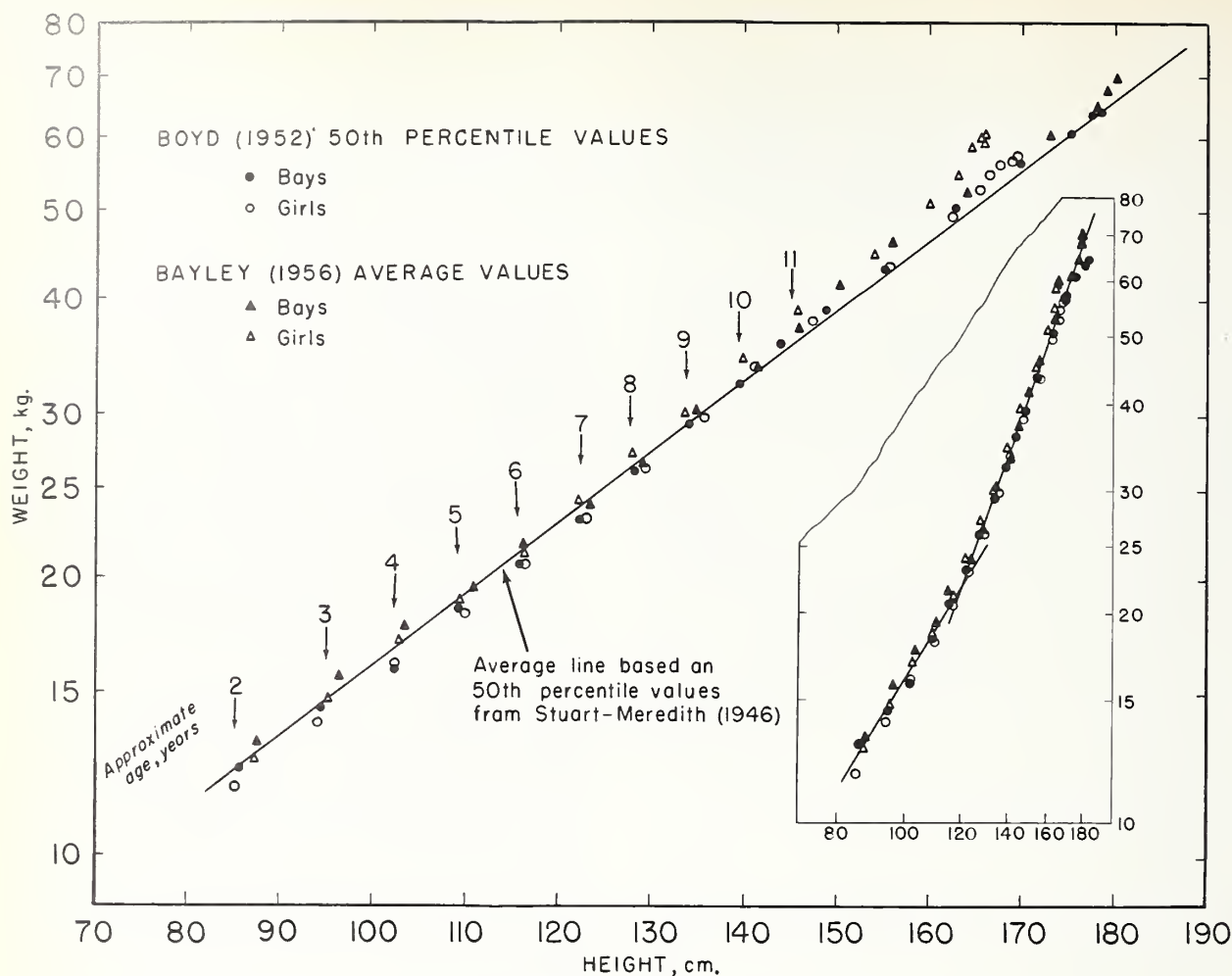


FIGURE 7.—Boyd (1952) and Bayley (1956) height-weight data plotted on a semilogarithmic grid.

The average line shown is that from figure 6. Ages corresponding to the data points are indicated. The insert shows the same data plotted on a logarithmic grid.

Asmussen and Heebøll-Nielsen (1956) reported that girls had shorter legs and longer trunks than boys. This difference was slight but consistent until a height of about 150 centimeters was reached (corresponding to the average height of a Danish girl 13 years of age, which is close to the mean age of puberty), when it became exaggerated. These workers also reported that the slopes of the regression lines representing the weight-height relation were slightly steeper for boys and girls taller than 145 centimeters than for those shorter than 145 centimeters, and that the difference in slope was greater between tall and short girls than between tall and short boys.

That average groups of boys and girls tend to become heavier in relation to their height at about the time of puberty may be due, in part, to the method of averaging data from population groups which are normally characterized by more overweight than underweight cases (this will be evident from table 5). Furthermore, the per-

centage overweight a child may attain and still be considered physically normal is much greater than the percentage underweight a child may attain and not be considered emaciated (abnormal). Therefore, the average weight of a population sample will tend to be higher (if children with excessive weights are included) in relation to the average height, which will not be affected by this biological phenomenon. Since after puberty there is a greater tendency for girls to add fatty tissue than boys, the average weight of a group of girls will, no doubt, be heavier in relation to their height than a similar group of boys.

Thus, it appears that the relatively higher values of weight for height for average groups of boys and girls after puberty may be a distortion and is not to be desired. Hence, the average line representing the relationship between weight and height of younger children (although not representative of the average relationship for most population groups after puberty) may be preferable for ap-

plication to Postpubertal boys and girls. Therefore, we have classified the Postpubertal boys and girls according to weight for height as indicated by extending the straight line in figure 6 to include heights up to 190 centimeters.

In figure 6 the relationship between weight and height appears to be the same for boys and girls before puberty. However, figure 7 shows that for the same height, girls weigh slightly less than the boys for heights below about 120 centimeters, but are heavier than the boys for taller heights. As previously mentioned, Døssing (1952), and also Asmussen and Heebøll-Nielsen (1956), reported that the rate of increase in weight per unit increase in height was slightly higher for girls than for boys. For our purposes any difference in the relationship between weight and height of boys and girls is so slight that a distinction between the sexes was unnecessary, especially since the children were sometimes weighed without clothes and at other times, with varying amounts of clothes.

Since average weight for height of children plotted on semilogarithmic paper is a straight line, this relationship may be represented by the exponential growth curve (or Compound Interest Law):

$$W = Ae^{bH}$$

in which W represents weight in kilograms and H , height in centimeters; A , theoretically, is the value of W when H is zero, and b is the slope of the line or the instantaneous relative rate (or, when multiplied by 100, the percentage rate) of increase in weight per unit increase in height.

The slope of the line in figure 6 was estimated to be about 0.018, meaning that for each centimeter added to height, weight increased at a constant rate of 1.8 percent. The value of A was estimated to be 2.6. Thus, the equation relating weight to height for metric units was

$$W = 2.6e^{0.018H}$$

The equation for U.S. customary units (pounds and inches) was

$$W = 6.0e^{0.045H}$$

Similar values were reported by O'Brien *et al.* (1941).³ From measurements on 55,175 boys and 37,842 girls, the relative rate of increase in weight per centimeter of height was found to be 1.83 percent for boys aged 4 to 14 years and 2.06 for girls aged 4 to 11 years. Because the data were shown only on an arithmetic grid and reported as average height and weight for age, an evaluation of the relationship between weight and height for girls over 11 years and the significance of the greater increase for girls could not be made.

The 75th percentile values for weight plotted in relation to the 50th percentile values for height at a given age fall close to the line drawn 10 percent above the average line. Values for ages younger than 11 years for boys and 8 years for girls are slightly below the +10 percent line, while those for older ages are above the +10 percent line and the deviations become increasingly greater with advancing age. Similarly, the 25th percentile values for weight plotted in relation to the 50th percentile values for height at a given age fall close to the line drawn 10 percent below the average line. For most ages the plotted values fall slightly above the line until age 14 years for girls and 16 years for boys, at which time the deviations become greater.

That this relationship between weight and height is applicable to children large or small for their age (both height and weight in the same percentile) is evident, since the height and weight values for the 25th and 75th percentiles from the Stuart-Meredith Standards (1946) fall very close to the average line based on the 50th percentile values. Height and weight values for the 10th and 90th percentiles deviate more, but are within plus and minus 10 percent of the average line.

The average line from figure 6, drawn through the 50th percentile values and represented by the equation,

$$W = 2.6e^{0.018H}$$

was the basis for the six weight-for-height classifications shown in figure 8. Children whose weight for height (regardless of age) fell within plus and minus 10 percent of this average line were classified in the "Normal" weight-for-height classification. Children weighing more in relation to their weight were classified as "Stocky" if their weight for height fell between 10 and 20 percent above the average line; "Overweight" for height if between 20 and 40 percent above; or "Obese" if 40 percent or more above. Children weighing less in relation to their height were classified as "Slender" if their weight for height fell between 10 and 20 percent below the average line, or "Underweight" for height if more than 20 percent below.

This classification is not meant to indicate the percentage overweight or underweight a child may be; it is simply a means of classifying children into groups that are more homogenous than classifications based on average height or weight for age. Children within the Stocky classification may have a large bony skeleton or may be more muscular than children in the Normal or Slender classifications but may not be overweight or approaching overweight; this classification also may include children who have a small bony skeleton but have adipose tissue. Similar comparisons may be made for the other classifications.

³ Out of print: available in libraries in most large cities.

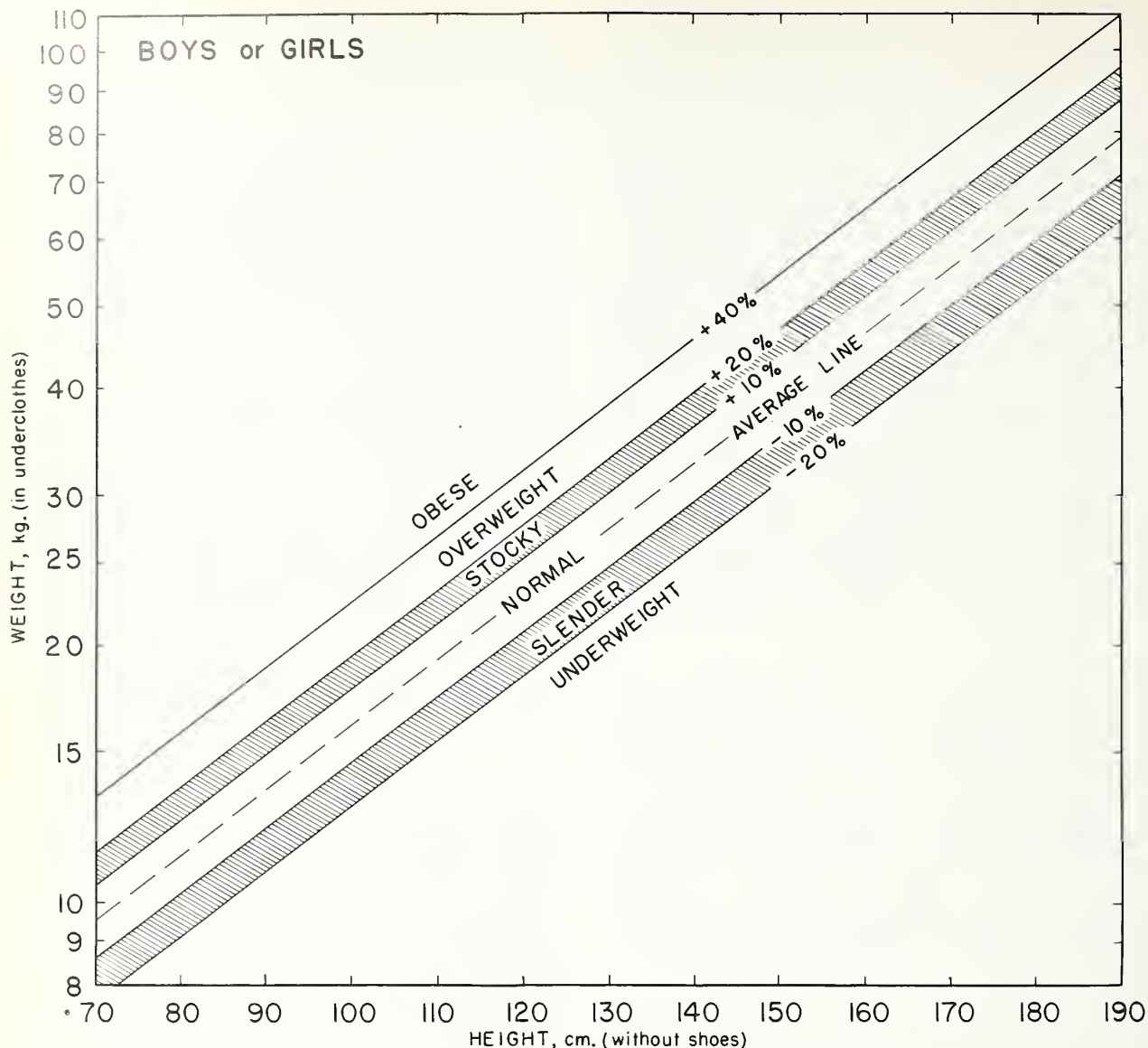


FIGURE 8.—WEIGHT-FOR-HEIGHT CLASSIFICATION OF CHILDREN: Metric units.

Values used to establish the average line were as follows: For 100 cm., 16.1 kg.; for 130 cm., 27.3 kg.; and for 160 cm., 46.3 kg.

The relationship between weight and height during growth of individual children is illustrated in figure 9 for ages 2 to 16 years and in figure 10 for ages 12 to 18 years. Children may have approximately the same height for age (upper sections, figure 9) but be in a different weight-for-height classification (lower sections, figure 9) throughout the age span 3 to 16 years.

Conversely, children may have the same weight-for-height classification, yet may be tall or short for their age as illustrated for children 12 to 18 years old in figure 10. Note that in figures 9 and 10 an upward trend at the end of the curves occurred more often for girls than for boys and

was more pronounced for short girls than for tall girls. In some children (for example, *see* numbers 103 and 33, figure 9) weight increased out-of-proportion to height, and thus changed from a Normal to an Overweight weight-for-height classification.

Figure 11 indicates that heat production of children classified as Stocky or Overweight may be lower than that of children of the same weight but within the Normal weight-for-height classification. There are indications also (*see* left sections of figure 11) that as the relationship between weight and height changed from Normal to Stocky or Overweight, the curve correlating

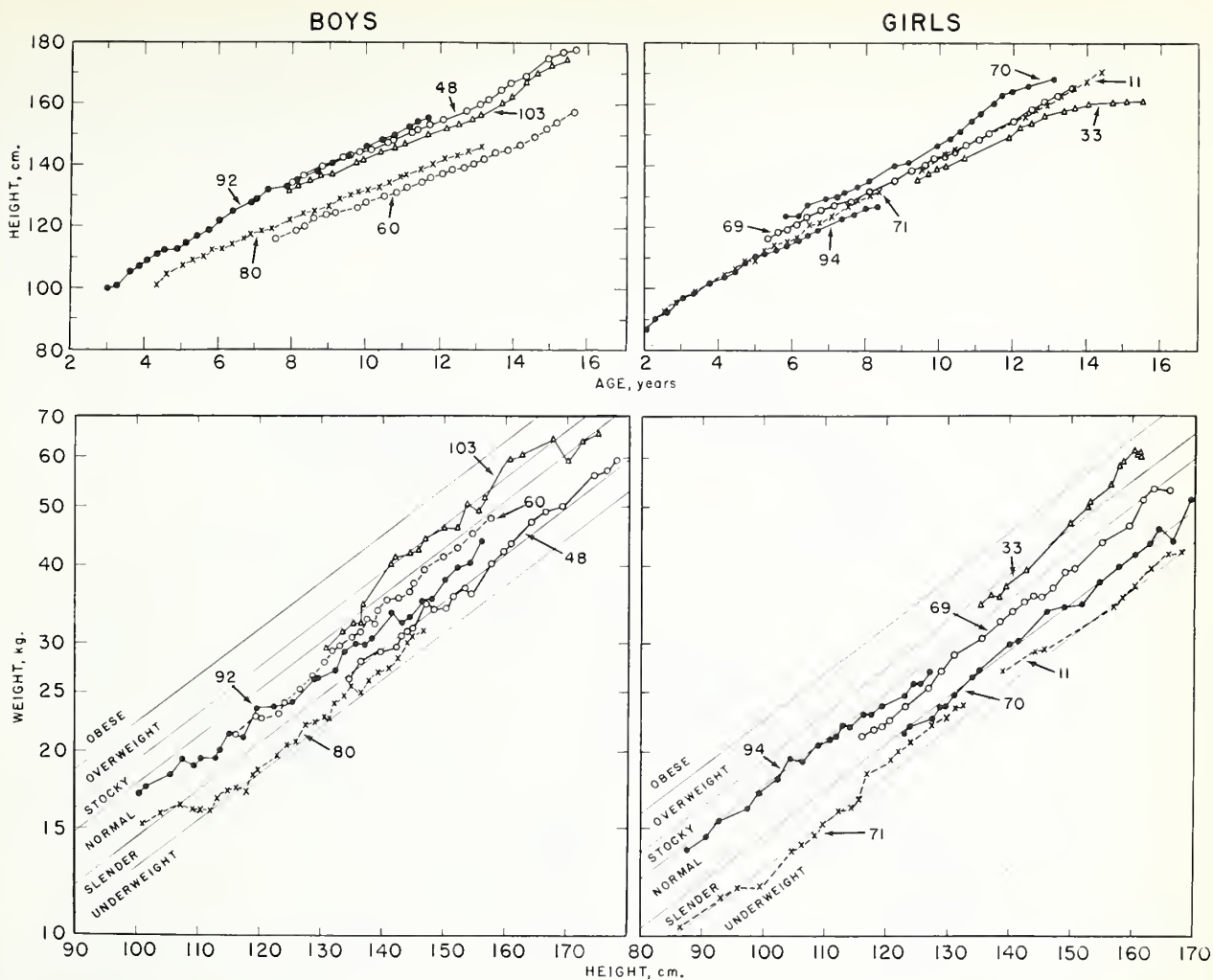


FIGURE 9.—COLORADO BOYS AND GIRLS 2 TO 16 YEARS OLD: Longitudinal data showing variations in weight-for-height classifications for individual boys and girls.

Height for age is given in the upper section to show that children may have approximately the same height but a different weight-for-height classification or may be of different height but be in the same weight-for-height classification. Data from Lewis, Kinsman, and Iliff (1937) and Duval (1942).

heat production with weight changed to a lower level. Thus, the next step in the data analysis was to determine whether there were significant differences in the heat production of children within the different weight-for-height classifications (section VII).

For this purpose the children for whom we obtained basal metabolic data were classified on the basis of their weight for height (disregarding chronological age) into the six classifications shown in figure 8. A further division was made on the basis of age by dividing each classification

into three physiological age intervals (Preschool, School Age to Puberty, Postpubertal to 16 years for girls and to 18 years for boys) as established in the preceding section from analysis of the longitudinal data. Data obtained for girls 16 years and older and boys 18 years and older included with data in the studies on younger children were analyzed for comparative purposes, but they are not to be considered complete. The number of measurements for each of these classifications is given in table 5.

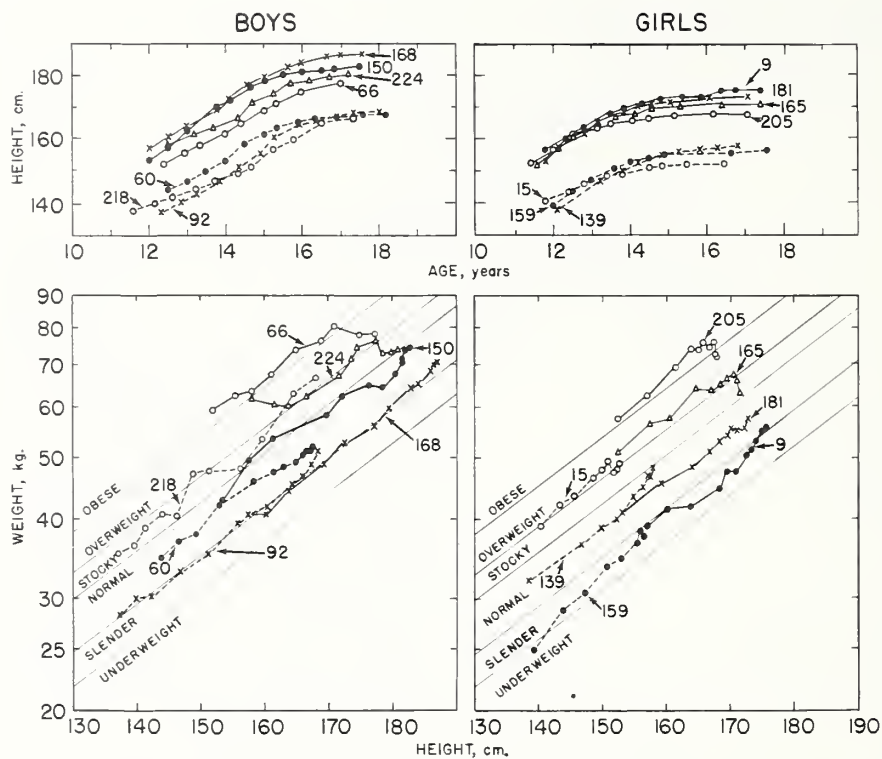


FIGURE 10.—CALIFORNIA BOYS AND GIRLS 12 TO 18 YEARS OLD: Longitudinal data showing variations in weight-for-height classifications (lower sections) of individual boys and girls tall and short for their age (height for age in upper section).

Data from Eichorn (n.p.).

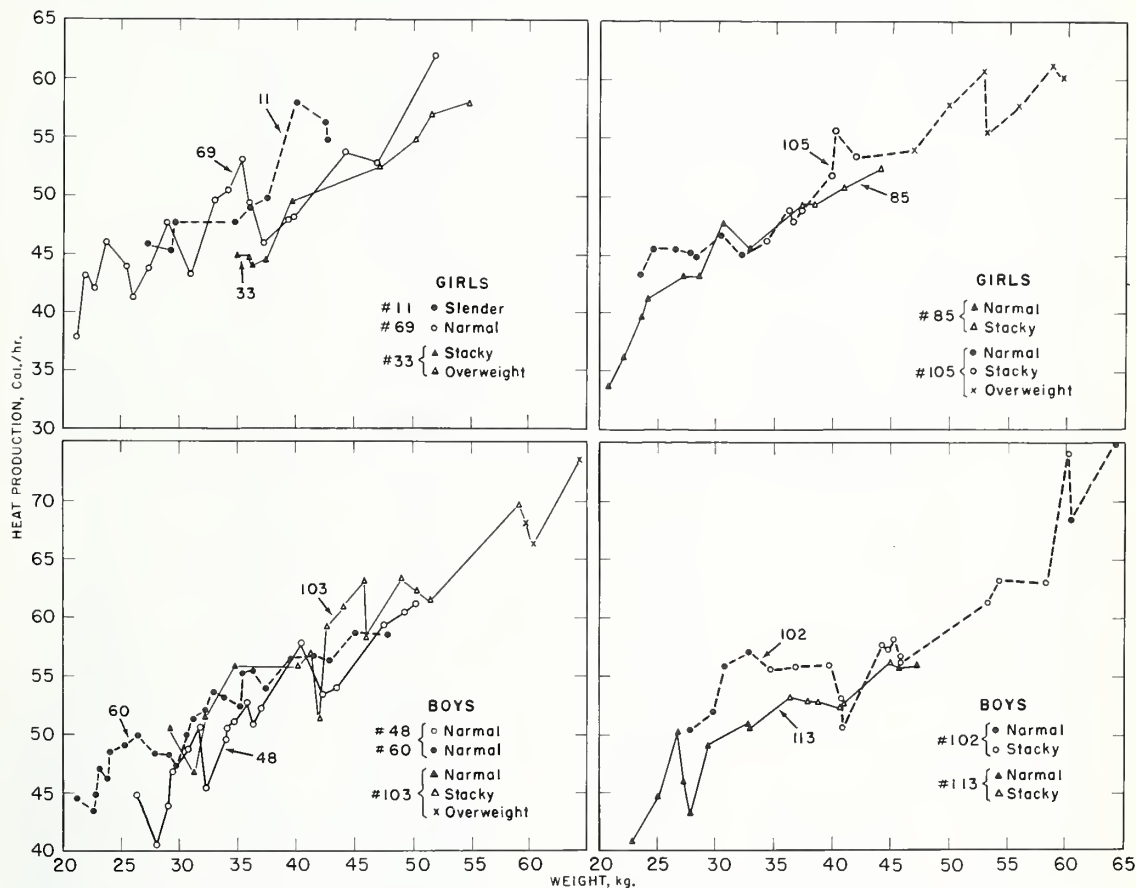


FIGURE 11.—Heat production in relation to weight for children within different weight-for-height classifications and for children in which the weight-for-height classification has changed from Normal to Stocky to Overweight with increasing age.

Data from Lewis, Kinsman, and Iliff (1937) and Duval (1942). See figure 9 for the weight-for-height classification of girls numbered 11, 35, and 69 and boys numbered 48, 60, and 103.

TABLE 5.—Number of basal metabolic measurements on children within each weight-for-height classification for each age interval

Location	Investigator(s) ¹	Boys						Girls							
		Weight-for-height classification ²						Weight-for-height classification ²							
		Under-weight	Slender	Normal	Stocky	Over-weight	Obese	Under-weight	Slender	Normal	Stocky	Over-weight	Obese		
		Preschool													
New York City	Taylor (n.p.)	0	0	11	0	0	0	11	0	0	9	1	1	0	11
Illinois and Ohio	Wang (1934, 1939); Wang <i>et al.</i> (1926, 1936)	0	0	0	0	0	0	0	0	1	3	0	0	0	4
Texas	Lamb (n.p.)	0	1	20	4	0	0	25	0	0	14	2	0	0	16
Colorado	Lewis <i>et al.</i> (1937); Duval (1942)	0	29	167	2	0	0	198	2	37	114	0	0	0	153
School Age to Puberty ³															
Northeast Region:	Talbot <i>et al.</i> (1937)	0	8	127	34	15	4	188	0	7	143	4	2	0	22
Massachusetts	Taylor (n.p.)	6	10	29	9	22	23	99	7	20	37	10	21	24	241
New York City	Topper and Mulier (1929a, 1929b, 1932)	5	6	165	42	2	0	220	1	15	115	26	12	3	119
New York	Davenport <i>et al.</i> (1939)	0	10	60	12	10	0	92	1	9	23	3	1	0	37
Do	Webster <i>et al.</i> (1941)	1	0	1	1	13	18	34	0	2	0	2	12	16	32
New York City	Bruch (1939a, 1939b, 1942)														
North Central Region:	Orner (1935)	0	0	1	3	1	0	5							
Ohio	Wang (1934, 1939); Wang <i>et al.</i> (1926, 1936)	1	7	7	0	0	0	15	6	19	21	1	0	0	47
Illinois and Ohio	Morse (n.p.)	1	13	70	10	4	0	98	1	7	15	2	3	1	29
Illinois	Maroney and Johnston (1937)	0	2	12	2	1	0	17	0	0	13	5	1	0	19
Michigan	Hoobler (n.p.)	0	13	27	2	0	0	42	0	1	34	4	5	4	48
Do	Harrison (n.p.)								4	12	29	10	3	1	59
Kansas															
Southern Region: Texas	Lamb (n.p.)	0	2	22	0	0	0	24	0	0	21	2	0	0	23
Western Region:	Lewis <i>et al.</i> (1937); Duval (1942)	1	183	553	41	7	0	785	22	100	357	27	16	0	522
Colorado	Thompson (n.p.)	0	4	37	5	3	0	49	0	7	21	2	3	0	33
Arizona	Esselbaugh (n.p.)	0	30	268	51	16	9	374	1	25	86	34	27	3	176
Washington	Eichorn (n.p.)														
California															

	Postpubertal to 18 years					Postpubertal to 16 years				
Northeast Region:										
Massachusetts	Talbot <i>et al.</i> (1937)	0	0	2	5	1	0	8	0	32
New York City	Taylor (n.p.)	0	0	6	3	0	0	9	0	35
Do.	Topper and Mulier (1929a, 1929b, 1932)	0	0	16	12	0	0	28	0	55
New York	Davenport <i>et al.</i> (1939)	0	0	9	10	4	0	23	0	55
Do.	Webster <i>et al.</i> (1941)	0	0	0	0	1	2	3	0	39
New York City	Bruch (1939a, 1939b, 1942)	0	0	0	0	1	2	3	0	7
North Central Region:										
Ohio	McKay (1930)	0	1	7	3	4	0	15	0	30
Do.	Orner (1935)	0	1	7	3	4	0	15	0	8
Illinois and Ohio	Wang (1934, 1939); Wang <i>et al.</i> (1926, 1936)	0	1	20	7	3	0	31	0	17
Illinois	Morse (n.p.)	0	1	20	7	3	0	31	0	106
Michigan	Hoobler (n.p.)	0	1	20	7	3	0	31	0	45
Kansas	Harrison (n.p.)	0	1	20	7	3	0	31	0	38
Western Region:										
Colorado	Lewis <i>et al.</i> (1937); Duval (1942)	0	2	14	2	0	0	18	0	98
Arizona	Thompson (n.p.)	0	0	5	0	2	0	7	0	104
Washington	Esselbaugh (n.p.)	1	5	40	18	8	3	75	2	239
California	Eichorn (n.p.)	0	13	128	21	7	0	169	0	6
Northeast Region:										
Massachusetts	Talbot <i>et al.</i> (1937)	0	0	1	0	0	0	1	0	6
New York City	Taylor (n.p.)	0	0	1	0	0	0	1	0	24
Do.	Topper and Mulier (1929a, 1929b, 1932)	0	0	1	6	0	0	7	0	46
New York	Davenport <i>et al.</i> (1939)	0	0	1	6	0	0	7	0	6
Do.	Webster <i>et al.</i> (1941)	0	0	1	6	0	0	7	0	6
North Central Region:										
Ohio	McKay (1930)	0	0	1	0	0	0	1	0	66
Do.	Orner (1935)	0	0	1	0	0	0	1	0	8
Illinois and Ohio	Wang (1934, 1939); Wang <i>et al.</i> (1926, 1936)	0	0	1	0	0	0	1	0	1
Illinois	Morse (n.p.)	0	0	1	0	0	0	1	0	1
Michigan	Hoobler (n.p.)	0	0	1	0	0	0	1	0	38
Kansas	Harrison (n.p.)	0	0	1	0	0	0	1	0	38
Western Region:										
Arizona	Thompson (n.p.)	0	2	20	16	5	0	43	0	224
Washington	Esselbaugh (n.p.)	0	0	8	1	0	0	9	0	15
California	Eichorn (n.p.)	0	0	8	1	0	0	9	0	111

¹ For Literature References, see section XI.

² These classifications (shown in figure 8) are based on percentage values of the line representing the average weight-for-height classification as follows: Underweight, -20% or more; Slender, within -10% and -20%; Normal, within $\pm 10\%$; Stocky, within +10% and +20%; Overweight, within +20% and +40%; Obese, +40% or more.

³ "Puberty" as designated herein (see section V) is the age corresponding to the change in the rate of growth in height, or, for girls, the onset of menarche.

VII.—Correlation of Basal Metabolism With Weight

The available heat production data from each location (or investigator) were correlated with weight separately for each physiological age interval (Preschool, School Age to Puberty, and Postpubertal) and for each weight-for-height classification, since a linear relationship was found to exist between basal heat production and weight. Regression equations were derived for each location (investigator) having a weight

range of 15 kilograms or more and 12 measurements or more on children of a given weight-for-height classification within a given age group. Exceptions to these conditions were made for the Preschool age interval.

It is often customary to make some selection of the measurements before reporting basal metabolic data (*see* table 2). Thus, the variability of these data has been reduced to a certain extent

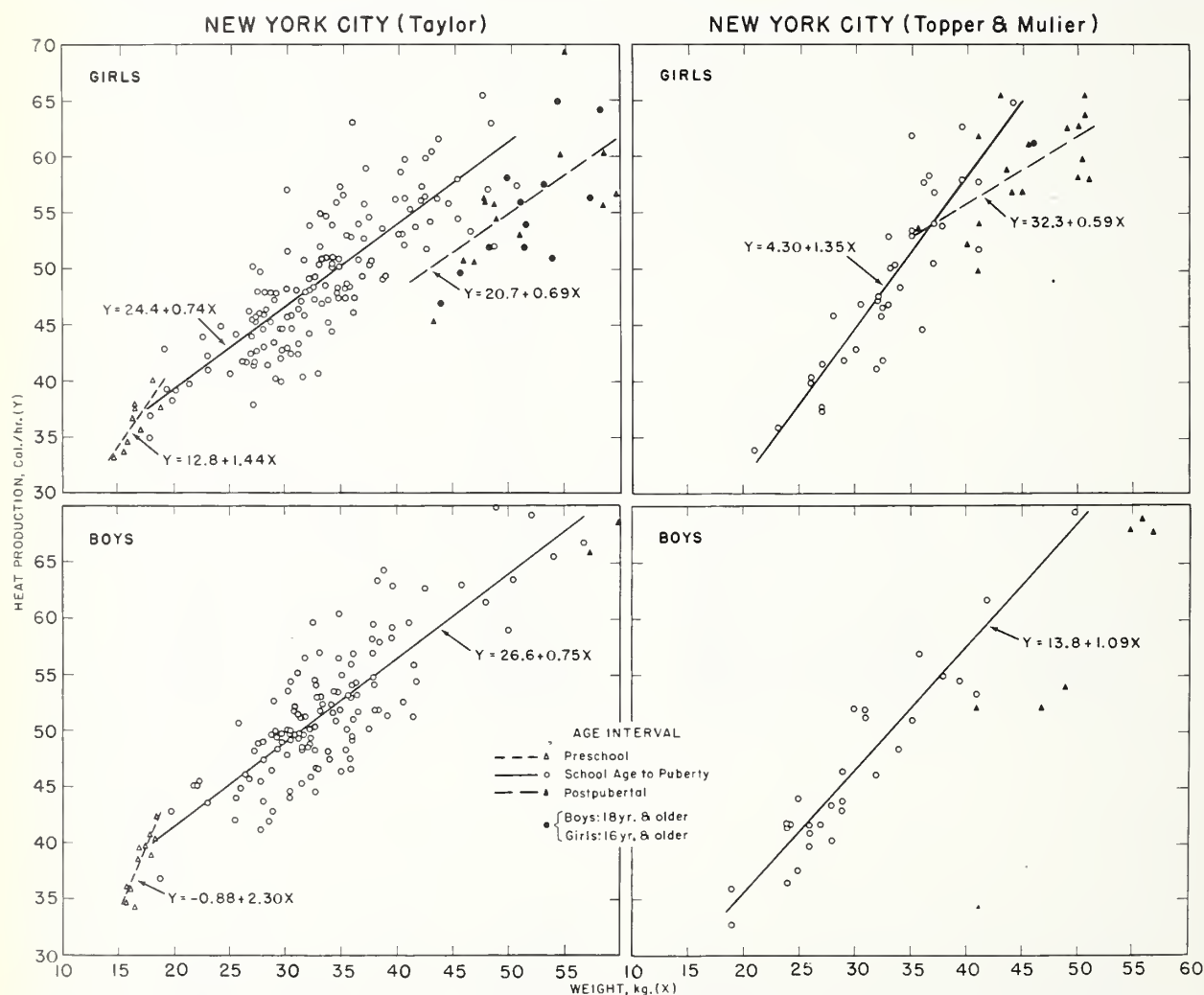


FIGURE 12.—NEW YORK CITY BOYS AND GIRLS WITHIN THE NORMAL WEIGHT-FOR-HEIGHT CLASSIFICATION: Relationship of basal heat production (Cal./hr.) to weight.

Individual data for the age intervals as indicated are shown and, when sufficient data are available, also the regression lines for each age interval. Data from Taylor (n.p.) and Topper and Mulier (1932).

(depending upon the procedure of selection by the investigator) before analysis, which is contrary to statistical theory. Nevertheless, statistical methods were employed as an aid in processing the data; for each group meeting the specification given above, the following statistical measures were computed:

The *regression equation*, $Y=a+bX$, fitted to the data by the method of least squares, expresses mathematically the average relationship between heat production (Y) and body weight (X). The constant, a in the equation, is the Y -intercept when X equals zero; it determines the height, or elevation of the regression line above the X -axis. The slope of the line, or regression coefficient, is symbolized by b in the equation; it determines the change in Y (heat production) per unit change in X (weight).

The *standard error of estimate*, or *standard deviation from regression*, measures the variability (in Calories per hour for the equations given herein) about the regression line. Two-thirds of the data points will fall

within plus and minus the standard error of estimate about the line of regression if the distribution approximates the normal.

The *correlation coefficient*, symbolized by r , measures the degree of relationship between heat production and weight. Values of r may range between one (a perfect relationship) and zero (no relationship).

FOR NORMAL AND SLENDER CHILDREN

Figures 12 through 17 present scatter diagrams, with derived equations, showing the regression of basal heat production on weight for boys and girls within the Normal weight-for-height classification. The statistical measures for each location are given in tables 6 for boys and 7 for girls.

That the increase in heat production per unit increase in weight is greater for the Preschool age interval than for the corresponding School

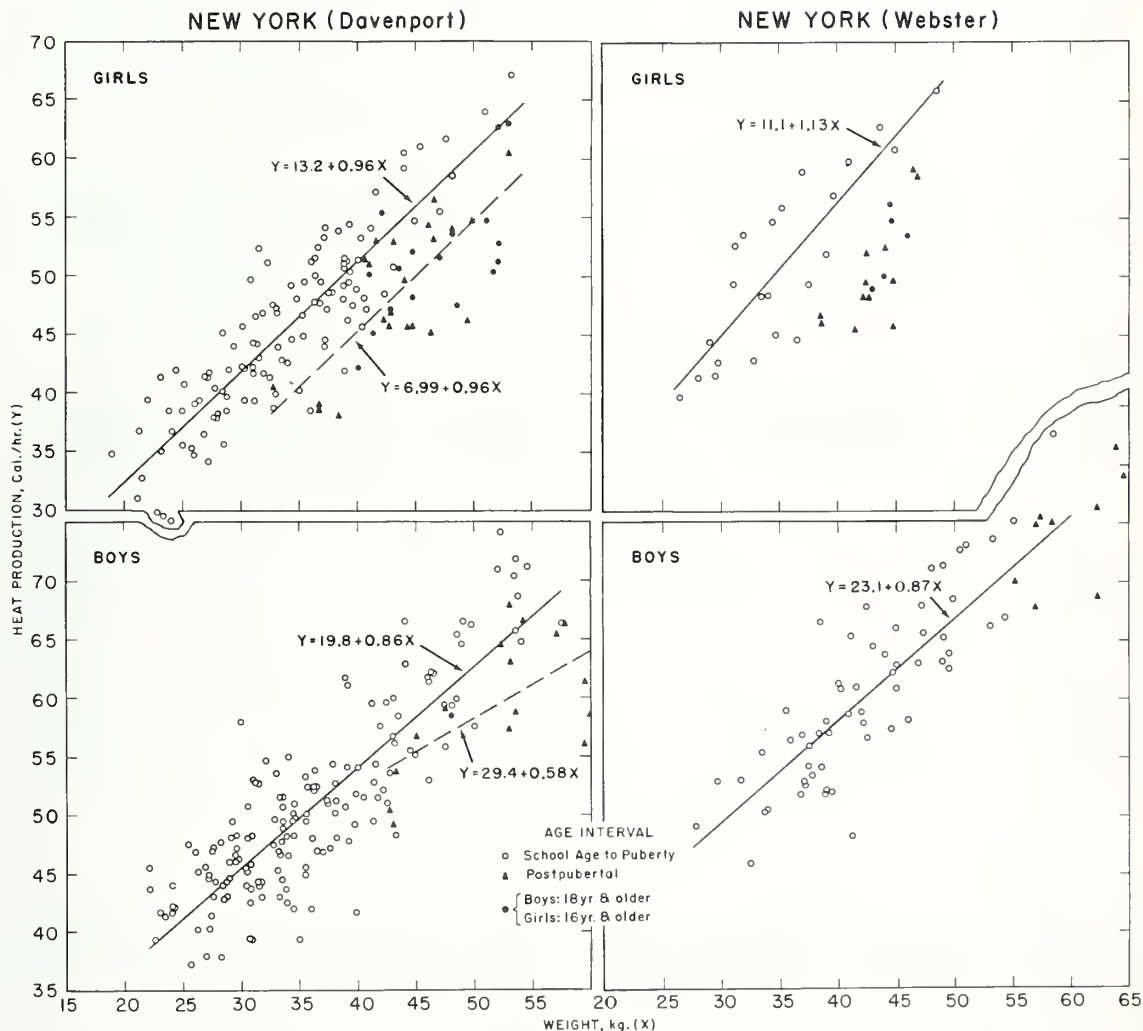


FIGURE 13.—NEW YORK BOYS AND GIRLS WITHIN THE NORMAL WEIGHT-FOR-HEIGHT CLASSIFICATION: Relationship of basal heat production (Cal./hr.) to weight.

Individual data for the age intervals as indicated are shown and, when sufficient data are available, also the regression lines for each age interval. Data from Davenport, Renfroe, and Hallock (1939) and Webster, Harrington, and Wright (1941).

TABLE 6.—BOYS WITHIN THE NORMAL AND SLENDERWEIGHT-FOR-HEIGHT CLASSIFICATIONS: *Regression production*

Location	Investigator(s) ²	Normal weight-for-height classification				
		Number of measurements	Weight range, kg.	Regression equation Y = Cal./hr. X = weight, kg.	Standard error of estimate	Correlation coefficient ³
Preschool						
New York City-----	Taylor (n.p.)-----	11	15. 7-18. 3	Y = -0. 88+2. 30X	1. 5	0. 85
Texas-----	Lamb (n.p.)-----	20	14. 0-19. 1	Y = 18. 4 +1. 17X	1. 9	. 64
Colorado-----	Lewis <i>et al.</i> (1937); Duval (1942).	167	12. 0-19. 8	Y = 17. 2 +1. 12X	2. 0	. 71
School Age to Puberty						
Northeast Region:						
New York City-----	Taylor (n.p.)-----	127	18. 7-56. 7	Y = 26. 6+0. 75X	3. 5	0. 81
Do-----	Topper and Mulier (1929b; 1932).	29	19. 0-50. 0	Y = 13. 8+1. 09X	2. 8	. 94
New York-----	Davenport <i>et al.</i> (1939).	165	22. 2-57. 5	Y = 19. 8+0. 86X	4. 1	. 86
Do-----	Webster <i>et al.</i> (1941)-----	60	27. 7-58. 4	Y = 23. 1+0. 87X	4. 5	. 81
North Central Region:						
Illinois and Ohio-----	Wang (1934, 1939), Wang <i>et al.</i> (1926, 1936).	7	13. 5-30. 8			
Illinois-----	Morse (n.p.)-----	70	23. 5-63. 1	Y = 20. 7+0. 93X	4. 9	. 86
Michigan-----	Maroney and Johnston (1937).	12	17. 2-32. 2	Y = 12. 9+1. 27X	1. 9	. 95
Do-----	Hoobler (n.p.)-----	27	16. 9-43. 6	Y = 21. 3+0. 98X	3. 0	. 91
Southern Region:						
Texas-----	Lamb (n.p.)-----	22	17. 2-46. 0	Y = 24. 6+0. 74X	1. 6	. 96
Western Region:						
Colorado-----	Lewis <i>et al.</i> (1937); Duval (1942).	553	15. 8-64. 3	Y = 25. 4+0. 74X	2. 8	. 90
Washington-----	Esselbaugh (n.p.)-----	37	40. 0-62. 3	Y = 18. 8+0. 89X	4. 8	. 67
California-----	Eichorn (n.p.)-----	268	27. 4-65. 2	Y = 19. 5+0. 95X	3. 8	. 89
Postpubertal to 18 years						
Northeast Region:						
New York-----	Davenport <i>et al.</i> (1939)-----	16	42. 7-60. 0	Y = 29. 4+0. 58X	4. 8	0. 61*
North Central Region:						
Illinois-----	Morse (n.p.)-----	20	51. 8-75. 7	Y = 61. 7+0. 19X	5. 6	. 20 N.S.
Western Region:						
Colorado-----	Lewis <i>et al.</i> (1937); Duval (1942).	14	49. 4-66. 1	Y = 3. 76+1. 05X	3. 3	. 89
Washington-----	Esselbaugh (n.p.)-----	40	50. 9-76. 8	Y = 16. 3+0. 79X	5. 6	. 62
California-----	Eichorn (n.p.)-----	128	45. 2-92. 2	Y = 16. 0+0. 90X	5. 4	. 76
18 years and older						
Arizona-----	Thompson (n.p.)-----	20	57. 7-82. 6	Y = 32. 5+0. 54X	4. 8	0. 62

¹ Equations were not derived for locations having less than 12 measurements and a weight range of less than

15 kg. within a given weight-for-height classification. Exception to this rule was made for Preschool age interval.

equations,¹ standard errors of estimate, and correlation coefficients for the linear relationship between heat and weight

Slender					Normal and Slender combined			
Number of measurements	Weight range, kg.	Regression equation Y=Cal./hr. X=weight, kg.	Standard error of estimate	Correlation coefficient ²	Number of measurements	Regression equation Y=Cal./hr. X=weight, kg.	Standard error of estimate	Correlation coefficient ³
Preschool—Continued								
0	15.4							
1	12.1-17.2	Y=9.93+1.66X	1.6	0.83	196	Y=16.9+1.14X	1.97	0.72
29								
School Age to Puberty—Continued								
8	17.0-32.0				135	Y=26.4+0.75X	3.5	0.82
10	15.0-45.0				39	Y=15.9+1.02X	3.2	.93
6	27.2-47.9				171	Y=19.7+0.86X	4.1	.86
10	30.4-37.3				70	Y=22.4+0.89X	4.4	.83
7	16.0-28.2				14	Y=25.4+0.81X	3.1	.84
13	17.3-54.1	Y=26.6+0.82X	5.1	0.88	83	Y=22.3+0.90X	5.0	.86
2	26.8, 29.0				14	Y=12.2+1.30X	2.0	.94
13	18.3-29.5				40	Y=21.7+0.99X	3.8	.86
2	20.8, 22.2							
183	15.9-52.6	Y=25.8+0.72X	2.8	.90	736	Y=25.5+0.74X	2.8	.90
4	45.8-56.6				41	Y=24.1+0.79X	5.8	.55
30	27.2-62.5	Y=26.7+0.76X	2.8	.94	298	Y=20.6+0.92X	3.7	.89
Postpubertal to 18 years—Continued								
0								
1	58.4							
2	53.1, 54.5				16	Y=5.91+1.02X	3.1	0.88
5	51.8-55.9				45	Y=27.6+0.62X	5.9	.55
13	52.9-61.3				141	Y=15.2+0.91X	5.3	.76
18 years and older—Continued								
2	66.4, 69.8							

² For Literature References, see section XI.

³ Significant at the 1-percent level unless otherwise indi-

cated; * = significant at the 5-percent level; N.S. = not significant.

TABLE 7.—GIRLS WITHIN THE NORMAL AND SLENDER WEIGHT-FOR-HEIGHT CLASSIFICATIONS:
relationship between heat

Location	Investigator(s) ²	Normal weight-for-height classification				
		Number of measurements	Weight range, kg.	Regression equation Y = Cal./hr. X = weight, kg.	Standard error of estimate	Correlation coefficient ³
Preschool						
New York City -----	Taylor (n.p.) -----	9	14. 6-18. 7	Y = 12.8 + 1.44X	1. 5	0. 79*
Texas -----	Lamb (n.p.) -----	14	12. 8-17. 4	Y = 7.79 + 1.63X	2. 2	. 70
Colorado -----	Lewis <i>et al.</i> (1937); Duval (1942) -----	114	11. 0-18. 7	Y = 12.4 + 1.31X	1. 7	. 78
School Age to Puberty						
Northeast Region:						
Massachusetts -----	Talbot <i>et al.</i> (1937) -----	16	33. 3-57. 6	Y = 5.90 + 1.29X	7. 3	0. 75
New York City -----	Taylor (n.p.) -----	143	17. 7-50. 7	Y = 24.4 + 0.74X	3. 6	. 82
Do -----	Topper and Mulier (1929b, 1932). -----	37	21. 0-40. 9	Y = 4.30 + 1.35X	3. 8	. 88
New York -----	Davenport <i>et al.</i> (1939) -----	115	18. 7-53. 0	Y = 13.2 + 0.96X	3. 6	. 88
Do -----	Webster <i>et al.</i> (1941) -----	23	26. 4-48. 6	Y = 11.1 + 1.13X	4. 1	. 85
North Central Region:						
Illinois and Ohio -----	Wang (1934, 1939); Wang <i>et al.</i> (1926, 1936). -----	21	16. 4-46. 9	Y = 26.6 + 0.65X	2. 8	. 90
Illinois -----	Morse (n.p.) -----	15	22. 6-48. 9	Y = 25.0 + 0.67X	3. 5	. 88
Michigan -----	Maroney and Johnston (1937) -----	13	23. 1-40. 8	Y = 21.0 + 0.85X	3. 4	. 82
Do -----	Hoobler (n.p.) -----	34	16. 9-44. 1	Y = 19.1 + 0.99X	3. 3	. 94
Kansas -----	Harrison (n.p.) -----	29	25. 1-44. 5	Y = 23.5 + 0.83X	3. 2	. 82
Southern Region: Texas -----	Lamb (n.p.) -----	21	15. 4-36. 6	Y = 24.2 + 0.66X	2. 4	. 78
Western Region:						
Colorado -----	Lewis <i>et al.</i> (1937); Duval (1942) -----	357	15. 1-52. 8	Y = 23. 2 + 0.75X	2. 6	. 91
Arizona -----	Thompson (n.p.) -----	21	30. 8-52. 8	Y = 23.4 + 0.73X	3. 8	. 75
California -----	Eichorn (n.p.) -----	86	19. 5-51. 4	Y = 19.7 + 0.86X	3. 4	. 80
Postpubertal to 16 years						
Northeast Region:						
Massachusetts -----	Talbot <i>et al.</i> (1937) -----	16	46. 1-67. 5	Y = 32.9 + 0.53X	5. 3	0. 53*
New York City -----	Taylor (n.p.) -----	13	43. 2-59. 6	Y = 20.7 + 0.69X	4. 6	. 64*
Do -----	Topper and Mulier (1929b, 1932). -----	17	35. 5-51. 0	Y = 32.3 + 0.59X	3. 8	. 60*
New York -----	Davenport <i>et al.</i> (1939) -----	22	32. 7-52. 9	Y = 6.99 + 0.96X	4. 2	. 74
North Central Region:						
Ohio -----	McKay (1930) -----	15	39. 8-56. 4	Y = 16.7 + 0.83X	4. 0	. 69
Michigan -----	Hoobler (n.p.) -----	26	37. 2-55. 8	Y = 19.4 + 0.83X	4. 8	. 65
Kansas -----	Harrison (n.p.) -----	24	41. 5-53. 6			
Western Region:						
Colorado -----	Lewis <i>et al.</i> (1937); Duval (1942) -----	18	43. 9-61. 5	Y = 31.6 + 0.48X	4. 4	. 48*
Arizona -----	Thompson (n.p.) -----	48	38. 6-69. 1	Y = 29.4 + 0.49X	3. 5	. 62
Washington -----	Esselbaugh (n.p.) -----	41	39. 8-63. 4	Y = 42.5 + 0.18X	4. 2	. 19 N.S.
California -----	Eichorn (n.p.) -----	118	39. 5-55. 5	Y = 29.4 + 0.53X	4. 2	. 42
16 years and older						
North Central Region:						
Ohio -----	McKay (1930) -----	24	41. 3-56. 5	Y = 25.3 + 0.59X	3. 9	0. 58
Michigan -----	Hoobler (n.p.) -----	15	42. 8-56. 6	Y = 32.9 + 0.45X	4. 4	. 34 N.S.
Kansas -----	Harrison (n.p.) -----	23	43. 3-67. 6	Y = 19.8 + 0.64X	4. 0	. 70
Western Region:						
Arizona -----	Thompson (n.p.) -----	114	40. 6-69. 1	Y = 29.4 + 0.41X	4. 2	. 48
California -----	Eichorn (n.p.) -----	57	46. 0-65. 0	Y = 11.2 + 0.82X	4. 1	. 60

¹ Equations were not derived for locations having less than 12 measurements and a weight range of less than 15

kg. within a given weight-for-height classification. Exception to this rule was made for the Preschool age interval.

Regression equations,¹ standard errors of estimate, and correlation coefficients for the linear production and weight

Slender					Normal and Slender Combined			
Number of measurements	Weight range, kg.	Regression equation Y=Cal./hr. X=weight, kg.	Standard error of estimate	Correlation coefficient ³	Number of measurements	Regression equation Y=Cal./hr. X=weight, kg.	Standard error of estimate	Correlation coefficient ³
Preschool—Continued								
0 0 37	10. 1-15. 5	Y=7.21+1.74X	1. 5	0. 87	151	Y=12.0+1.35X	1. 7	0. 82
School Age to Puberty—Continued								
0 7 20	21. 0-28. 9 14. 0-44. 0	Y=1.51+1.56X	3. 9	0. 95	150 57	Y=23.8+0.76X Y=4.36+1.39X	3. 6 4. 2	0. 83 . 90
15 9	18. 8-32. 3 27. 5-37. 1				130 32	Y=13.4+0.95X Y=12.3+1.09X	3. 7 3. 9	. 88 . 83
19 7 0 1 12 0	17. 3-43. 8 21. 2-44. 6 33. 6 26. 5-37. 5	Y=26.4+0.67X	2. 3	. 92	40 22 41	Y=26.6+0.65X Y=26.4+0.65X Y=23.5+0.82X	2. 5 4. 0 3. 2	. 91 . 82 . 81
100 7 25	12. 6-44. 3 35. 6-44. 9 18. 5-48. 0	Y=20.0+0.87X Y=21.9+0.83X	1. 9 3. 6	. 96 . 86	457 28 111	Y=22.3+0.78X Y=23.6+0.73X Y=21.1+0.83X	2. 5 3. 5 3. 4	. 92 . 77 . 82
Postpubertal to 16 years—Continued								
0 4 6 0 0 1 4 6 8 2 6	44. 4-52. 8 34. 0-42. 0 40. 1 44. 4-57. 6 45. 6-50. 9 36. 8-49. 7 46. 6-47. 5 33. 9-52. 0				17 23 28 24 56 43 124	Y=26.1+0.59X Y=31.7+0.61X Y=23.2+0.64X Y=37.7+0.37X Y=30.4+0.48X Y=44.6+0.14X Y=26.5+0.59X	4. 3 3. 5 4. 0 4. 0 3. 4 4. 4 4. 3	0. 59* . 70 . 55 . 41* . 64 . 15 N.S. . 50
16 years and older—Continued								
0 0 1 5 2	44. 6 44. 0-59. 4 37. 7, 38. 5							

² For Literature references, see section XI.

³ Significant at the 1-percent level unless otherwise indi-

cated: *=significant at the 5-percent level; N.S.=not significant.

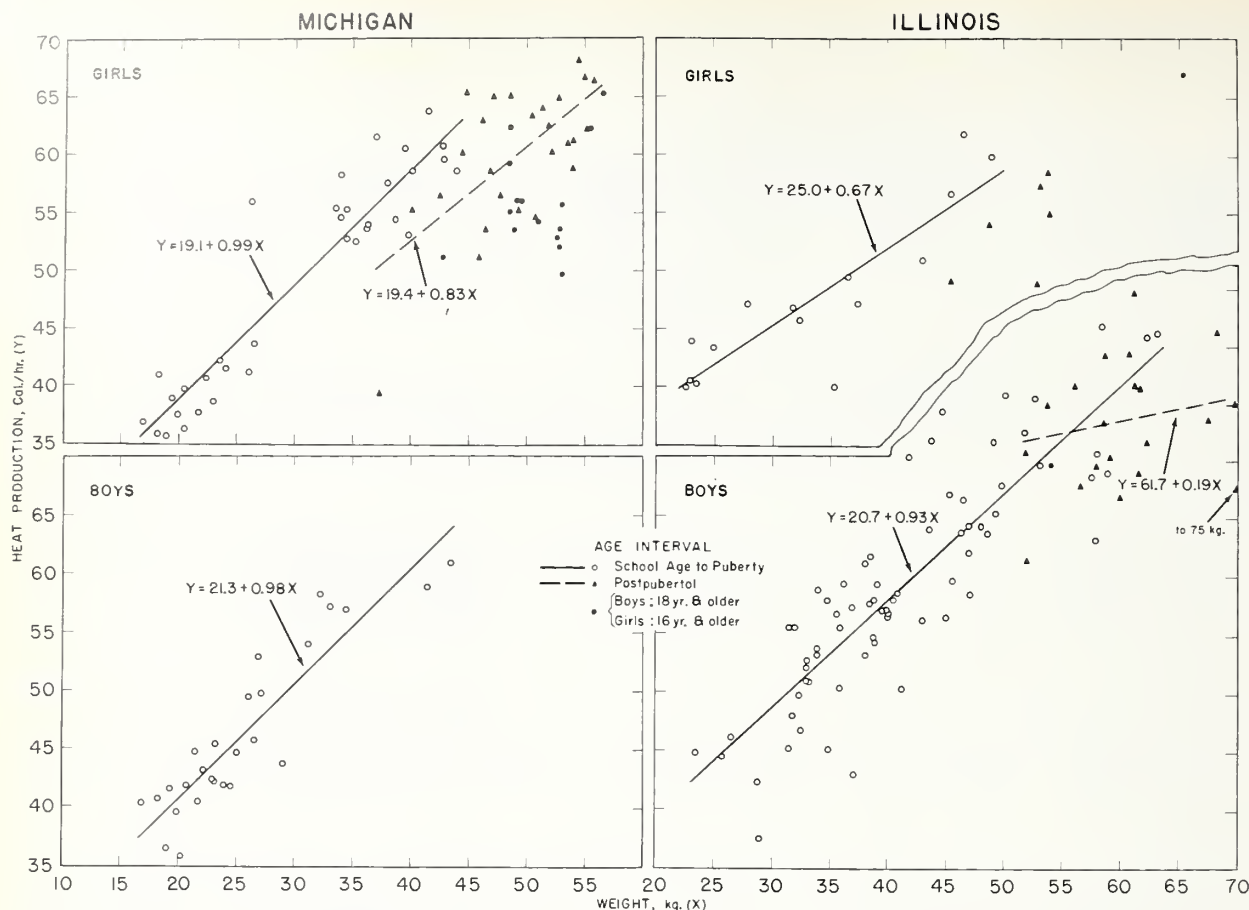


FIGURE 14.—MICHIGAN AND ILLINOIS BOYS AND GIRLS WITHIN THE NORMAL WEIGHT-FOR-HEIGHT CLASSIFICATION: Relationship of basal heat production (Cal./hr.) to weight.

Individual data for the age intervals as indicated are shown and, when sufficient data are available, also the regression lines for each age interval. Data for Michigan children, from Hoobler (n.p.) and for Illinois children, from Morse (n.p.).

Age to Puberty age interval is shown by the steeper regression lines for the Preschool age interval (figures 12 and 15). The increase in heat production per unit increase in weight is, on the average, greater than unity for the Preschool age interval and less than unity for the corresponding School Age to Puberty age interval.

That heat production is lower for boys and girls after puberty is shown by the decidedly lower elevation of the regression lines for the Postpubertal age interval as compared with the regression lines for the School Age to Puberty age interval. However, the regression lines for the Postpubertal age interval are not so low in elevation as the regression lines for girls 16 years and older (shown in figures 16 and 17). Therefore, for a given weight, heat production is lower in boys and girls after than before puberty and is still lower after maturity is reached.

In addition to this lower level of heat production after puberty, there is also a change in the metabolic rate (change in heat production per

unit change in weight) as indicated by a change in slope—the regression lines for the Postpubertal age interval tend to be somewhat flatter than those for either the younger or older age intervals. This conclusion substantiates the statement presented in section V, that the metabolism during the Postpubertal age interval reflects the physiological adjustment necessary to change from the higher metabolic rate of a growing child to the lower metabolic rate of an adult. It also was noted in section V, that heat production was usually more variable after than before puberty; this was reflected by the larger standard errors of estimate obtained for the Postpubertal age intervals and by the wide range in slopes of the regression lines for the various locations.

Figure 18 shows scatter diagrams and the regression lines derived for Slender children from two locations. Statistical measures for these locations and for the other locations having sufficient data on Slender children for analysis also are given in tables 6 and 7. The regression lines

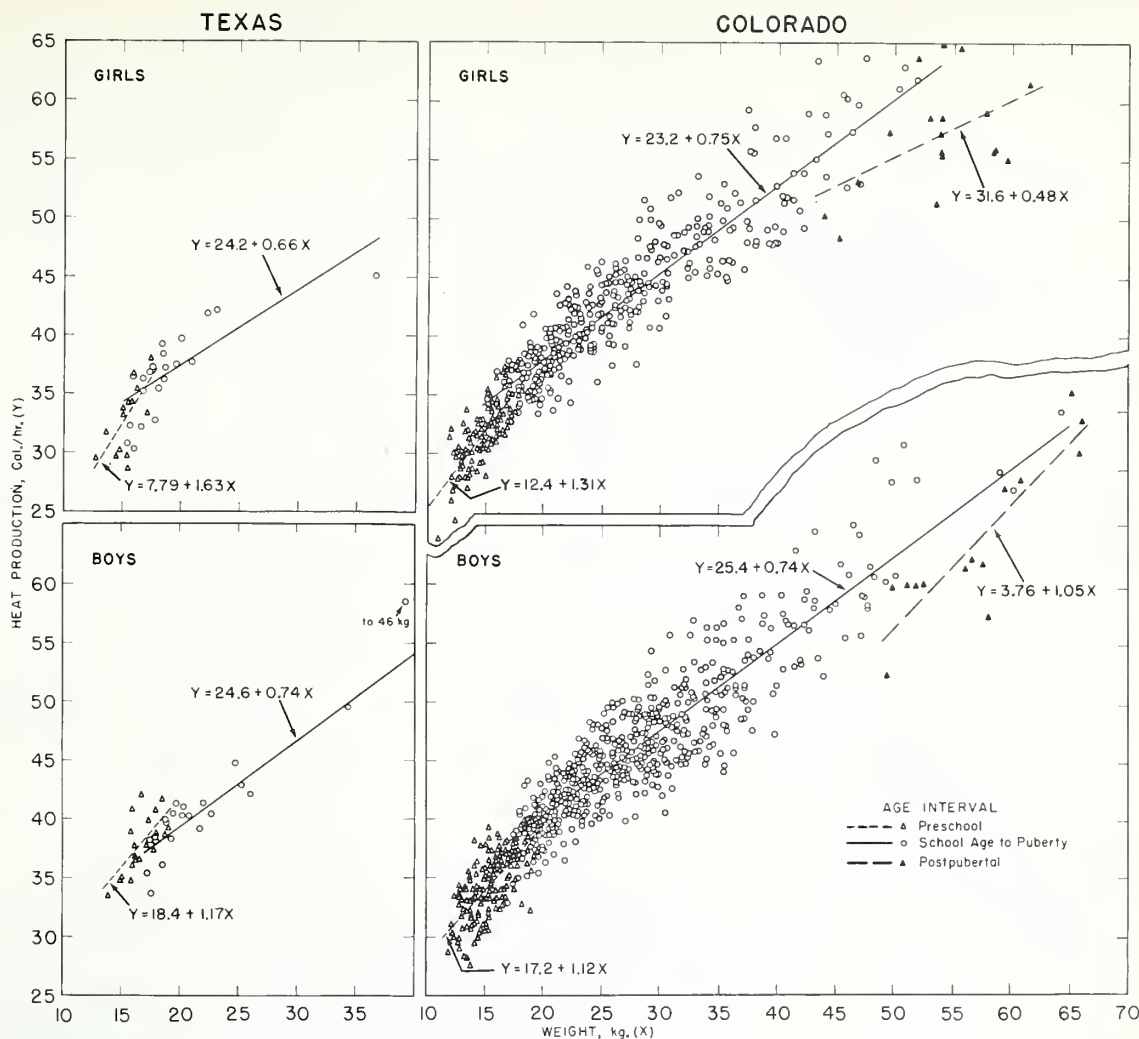


FIGURE 15.—TEXAS AND COLORADO BOYS AND GIRLS WITHIN THE NORMAL WEIGHT-FOR-HEIGHT CLASSIFICATION: Relationship of basal heat production (Cal./hr.) to weight.

Individual data for the age intervals as indicated are shown along with the regression lines for each. Data for Texas children, from Lamb (n.p.) and for Colorado children, from Lewis, Kinsman, and Iliff (1937) and Duval (1942).

are slightly steeper for the Slender girls but less steep for the Slender boys than are the corresponding regression lines derived for children within the Normal weight-for-height classifications. This difference between the slopes causes the regression lines for Slender children to cross those for children within the Normal weight-for-height classification.

To determine whether the differences in slope and elevation of the regression lines for the Normal and Slender weight-for-height classifications were statistically significant, analysis of covariance was used (Snedecor, 1956). Table 8 briefly summarizes the results of these tests on the Preschool and School Age to Puberty age intervals. Measurements on Slender children from any one location within the Postpubertal age interval were not considered adequate for analysis.

Although the tests indicated that for three of

the nine pairs there was a significant difference between the slopes of the regression lines, these differences are attributed to some factor other than to a real difference. This interpretation arises from the fact that for the School Age to Puberty age interval, the difference was significant for one sex from one location and for the opposite sex from a different location. Furthermore, the regression line for the Slender girls had the steeper slope, whereas the regression line for the boys within the Normal weight-for-height classification was the steeper. The differences in elevation of the regression lines for Normal and Slender girls were not significant except from data for girls reported by Topper and Mulier.

Since the conclusion from the data presented herein is that heat production per unit of weight is the same (at least the difference is not statistically significant) for children within the Slender

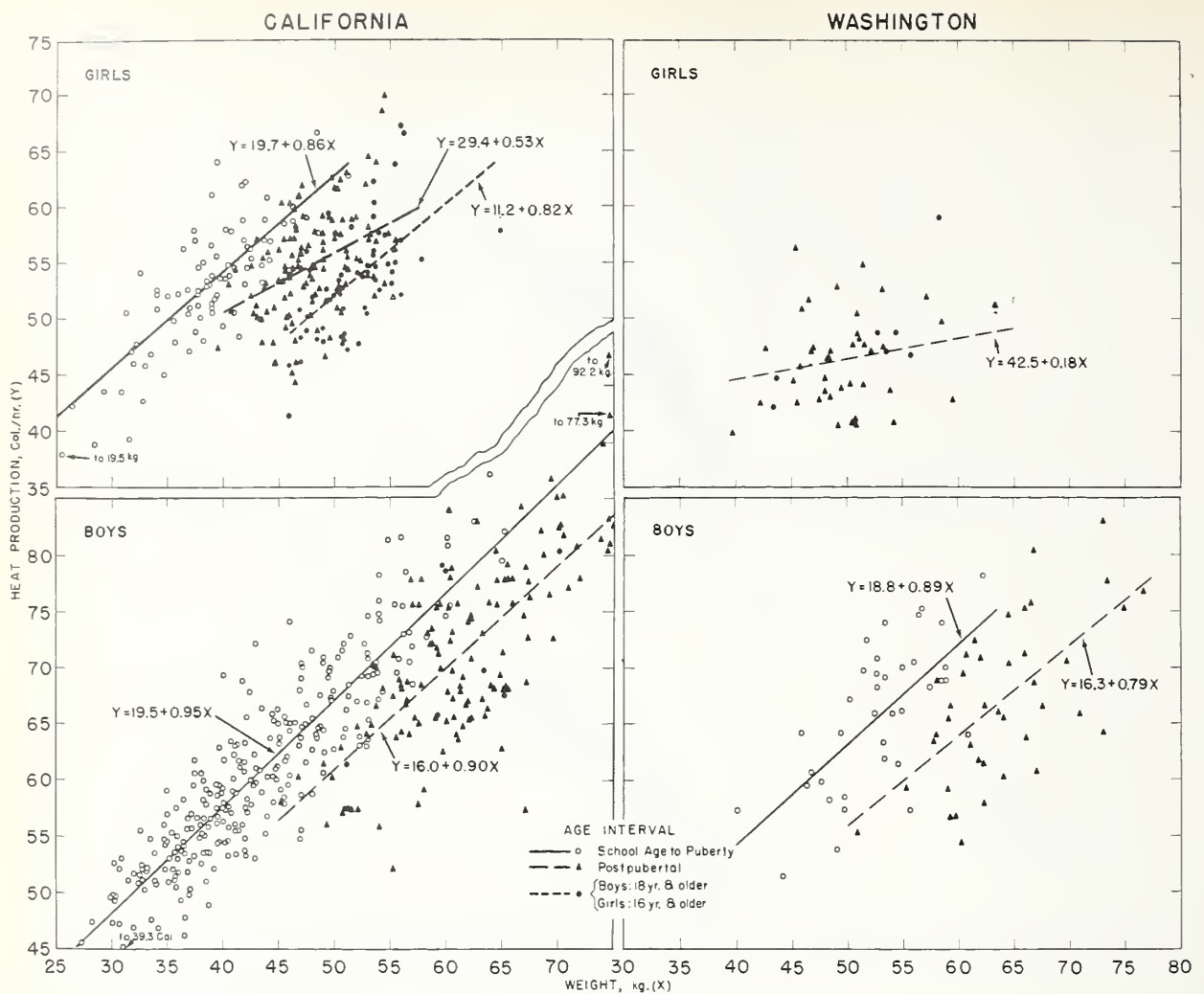


FIGURE 16.—CALIFORNIA AND WASHINGTON BOYS AND GIRLS WITHIN THE NORMAL WEIGHT-FOR-HEIGHT CLASSIFICATION: Relationship of basal heat production (Cal./hr.) to weight.

Individual data for the age intervals as indicated are shown and, when sufficient data are available, also the regression lines for each age interval. Data for California children, from Eichorn (n.p.) and for Washington children, from Esselbaugh (n.p.).

and Normal weight-for-height classifications within a given location, the data have been combined. The equations (and other statistical measures) derived from this combination are given in tables 6 and 7, and are the equations used in section IX for integration; however, for simplicity these equations are referred to as the equations derived from data for children within the *Normal* weight-for-height classification.

FOR STOCKY AND OVERWEIGHT CHILDREN

Figures 19 and 20 present scatter diagrams and regression lines derived for boys and girls within the School Age to Puberty age intervals having Stocky and Overweight weight-for-height classifications. For additional data for Overweight

children *see* figure 23. The statistical measures computed are given in tables 9 and 10.

When the regression lines derived for the three weight-for-height classifications — Normal, Stocky, and Overweight — within a given location are compared, the lines for the Stocky and the Overweight boys and girls are usually at a decidedly lower elevation than those for boys and girls in the Normal classification. Hence, for a given weight, Stocky and Overweight boys and girls have a lower heat production than children in the Normal weight-for-height classification. However, it is debatable whether the metabolic rate (increase in heat production per unit increase in weight) is different for all weight-for-height classification within a given age interval, since for some locations the slopes of the regression lines for the Stocky and the Overweight are flatter, in

GIRLS

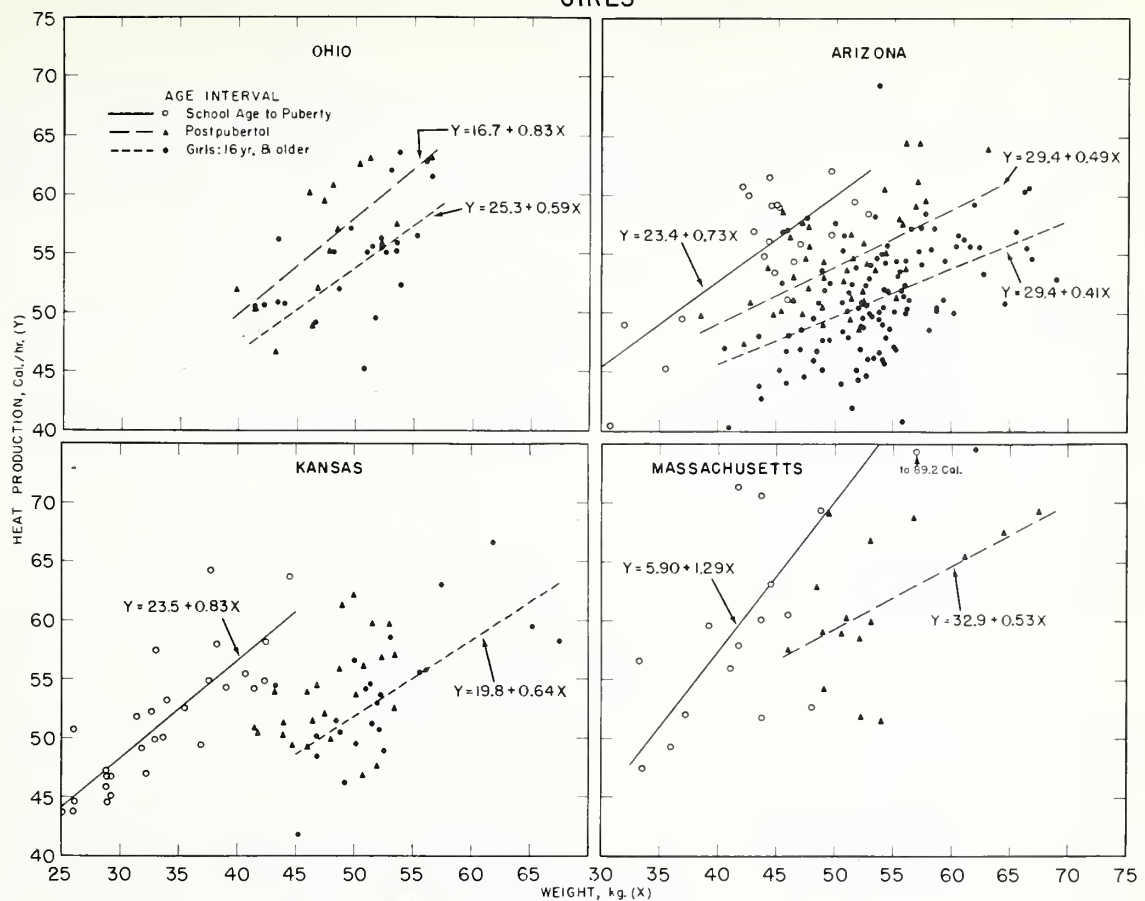


FIGURE 17.—OHIO, ARIZONA, KANSAS, AND MASSACHUSETTS GIRLS WITHIN THE NORMAL WEIGHT-FOR-HEIGHT CLASSIFICATION: Relationship of basal heat production (Cal./hr.) to weight.

Individual data for the age intervals as indicated are shown along with the regression lines for each. Data for Ohio, from McKay (1930); for Arizona, from Thompson (n.p.); for Kansas, from Harrison (n.p.); and for Massachusetts, from Talbot, Wilson, and Worcester (1937).

TABLE 8.—Boys and girls within the Normal and slender weight-for-height classifications: *Summary*¹ of results obtained from covariance analysis for comparison of the regression of heat production on weight

Location	Investigator(s) ²	Sex	Test for difference in slope ³	Test for difference in elevation ³
		Preschool		
Colorado -----	Lewis <i>et al.</i> (1937); Duval (1942) -----	Boys ----- Girls -----	N.S. (*)	N.S. N.S.
		School Age to Puberty		
New York City -----	Topper and Mulier (1929b, 1932) -----	Girls -----	N.S.	(**)
Illinois and Ohio -----	Wang (1934, 1939); Wang <i>et al.</i> (1926, 1936). -----	Girls -----	N.S.	N.S.
Illinois -----	Morse (n.p.) -----	Boys -----	N.S.	N.S.
Colorado -----	Lewis <i>et al.</i> (1937); Duval (1942) -----	Boys ----- Girls -----	N.S. (**)	N.S. N.S.
California -----	Eichorn (n.p.) -----	Boys ----- Girls -----	(**) N.S.	N.S. N.S.

¹ See tables 21 and 22 (appendix) for numerical values.

² For Literature References, see section XI.

³ N.S.=not significant; *=significant at the 5-percent level; **=significant at the 1-percent level.

TABLE 9.—STOCKY AND OVERWEIGHT BOYS: *Regression equations,¹ standard errors of estimate,*

Location	Investigator(s) ²	Stocky				
		Num- ber of measure- ments	Weight range, kg.	Regression equation Y = Cal./hr. X = weight, kg.	Standard error of estimate	Correlation coefficient ³
School Age to Puberty						
Northeast Region:						
New York City-----	Taylor (n.p.)-----	34	23. 3-59. 6	Y = 18.5 + 0.93X	4. 5	0. 85
Do-----	Topper and Mulier (1929a, 1929b, 1932).	9	25. 0-63. 0			
New York-----	Davenport <i>et al.</i> (1939)-----	42	30. 1-64. 0	Y = 20.5 + 0.80X	4. 1	. 84
Do-----	Webster <i>et al.</i> (1941)-----	12	41. 1-64. 9	Y = 13.6 + 0.91X	4. 4	. 83
New York City-----	Bruch (1939a, 1939b, 1942)-----	1	29. 1			
North Central Region:						
Illinois-----	Morse (n.p.)-----	10	40. 9-62. 8			
Western Region:						
Colorado-----	Lewis <i>et al.</i> (1937); Duval (1942).	41	24. 3-64. 0	Y = 24.4 + 0.76X	2. 9	. 92
California-----	Eichorn (n.p.)-----	51	28. 6-67. 0	Y = 26.0 + 0.78X	5. 8	. 70
Postpubertal to 18 years						
Northeast Region:						
New York-----	Davenport <i>et al.</i> (1939)-----	12	45. 6-61. 3	Y = 21.3 + 0.67X	5. 5	0. 54 N.S.
Do-----	Webster <i>et al.</i> (1941)-----	10	54. 7-70. 1			
Western Region:						
Washington-----	Esselbaugh (n.p.)-----	18	56. 7-82. 7	Y = 35.3 + 0.53X	4. 1	. 75
California-----	Eichorn (n.p.)-----	21	53. 0-76. 3	Y = 28.1 + 0.69X	5. 4	. 68
18 years and older						
Arizona-----	Thompson (n.p.)-----	16	64. 6-85. 7	Y = 45.9 + 0.39X	3. 4	0. 60*

¹ Equations were not derived for locations having less than 12 measurements and a weight range of less than 15 kg. within a given weight-for-height classification.

Overweight					Stocky and overweight combined			
Number of measurements	Weight range, kg.	Regression equation Y = Cal./hr. X = weight, kg.	Standard error of estimate	Correlation coefficient ³	Number of measurements	Regression equation Y = Cal./hr. X = weight, kg.	Standard error of estimate	Correlation coefficient ³
School Age to Puberty—Continued								
15	35.3–58.1	Y = 14.6 + 0.95X	4.1	0.79	49	Y = 20.6 + 0.86X	4.5	0.82
22	31.0–69.0	Y = 7.8 + 0.96X	3.9	.94	31	Y = 16.6 + 0.81X	4.4	.91
2	53.3, 59.7	-----	-----	-----	44	Y = 21.1 + 0.78X	4.0	.85
10	45.0–68.5	-----	-----	-----	22	Y = 18.6 + 0.79X	3.8	.88
13	30.8–62.7	Y = 33.3 + 0.49X	6.8	.54 N.S.	14	Y = 31.9 + 0.52X	6.6	.60*
4	50.9–58.2	-----	-----	-----	14	Y = 33.8 + 0.62X	5.7	.61*
7	30.8–64.2	-----	-----	-----	48	Y = 25.4 + 0.74X	2.8	.93
16	39.4–74.4	Y = 36.2 + 0.61X	6.3	.69	67	Y = 27.7 + 0.75X	5.9	.72
Postpubertal to 18 years—Continued								
0	-----	-----	-----	-----	-----	-----	-----	-----
4	62.6–70.9	-----	-----	-----	14	Y = 15.8 + 0.89X	6.2	0.63*
8	61.4–91.1	-----	-----	-----	26	Y = 42.2 + 0.42X	4.1	.71
7	62.8–78.1	-----	-----	-----	28	Y = 35.0 + 0.58X	5.2	.67
18 years and older—Continued								
5	61.8–79.9	-----	-----	-----	21	Y = 22.2 + 0.69X	5.5	0.64

² For Literature References, see section XI.³ Significant at the 1-percent level unless otherwise indicated: * = significant at the 5-percent level; N.S. = not significant.

TABLE 10.—STOCKY AND OVERWEIGHT GIRLS: *Regression equations,¹ standard errors of*

Location	Investigator(s) ²	Stocky				
		Number of meas- urements	Weight range, kg.	Regression equation Y = Cal./hr. X = weight, kg.	Standard error of estimate	Correlation coefficient ³
School Age to Puberty						
Northeast Region: New York City----- Do-----	Taylor (n.p.)----- Topper and Mulier (1929a, 1932).	45 10	25. 2-57. 4 38. 0-50. 0	Y = 26.9 + 0.66X	3. 9	0. 74
New York----- New York City-----	Davenport <i>et al.</i> (1939)--- Bruch (1939a, 1939b, 1942)	26 2	28. 1-50. 9 24. 1, 41. 0	Y = 18.3 + 0.76X	3. 5	. 80
North Central Region: Kansas-----	Harrison (n.p.)-----	10	37. 5-46. 5			
Western Region: Colorado----- California-----	Lewis <i>et al.</i> (1937); Duval (1942). Eichorn (n.p.)-----	27 34	19. 5-44. 7 30. 9-62. 8	Y = 22.1 + 0.74X Y = 23.4 + 0.73X	3. 2 3. 7	. 74 . 84
Postpubertal to 16 years						
Northeast Region: New York City----- Do-----	Taylor (n.p.)----- Topper and Mulier (1929a, 1932).	7 9	37. 5-63. 4 42. 0-49. 5			
New York-----	Davenport <i>et al.</i> (1939)---	18	37. 5-60. 0	Y = - 3.04 + 1.14X	6. 2	0. 73
North Central Region: Ohio----- Michigan----- Kansas-----	McKay (1930)----- Hoobler (n.p.)----- Harrison (n.p.)-----	11 50 10	44. 2-59. 0 42. 2-72. 1 52. 4-69. 2	Y = 39.7 + 0.38X	4. 1	. 44
Western Region: Arizona----- Washington----- California-----	Thompson (n.p.)----- Esselbaugh (n.p.)----- Eichorn (n.p.)-----	29 25 37	45. 6-68. 3 44. 8-68. 0 43. 8-61. 4	Y = 36.8 + 0.34X Y = 27.6 + 0.48X Y = 25.6 + 0.56X	5. 7 6. 0 4. 1	. 36 N.S. . 38 N.S. . 55
16 years and older						
Northeast Region: New York-----	Davenport <i>et al.</i> (1939)---	10	44. 1-56. 1			
North Central Region: Ohio----- Michigan-----	McKay (1930)----- Hoobler (n.p.)-----	22 20	45. 7-72. 1 46. 0-64. 3	Y = 27.2 + 0.52X Y = 16.4 + 0.76X	3. 7 4. 0	0. 65 . 68
Western Region: Arizona----- California-----	Thompson (n.p.)----- Eichorn (n.p.)-----	63 21	44. 7-72. 3 46. 0-66. 3	Y = 36.5 + 0.26X Y = 16.1 + 0.70X	4. 6 3. 9	. 29* . 77

¹ Equations were not derived for locations having less than 12 measurements and a weight range of less than 15 kg. within a given weight-for-height classification.

² For Literature References, see section XI.

estimate, and correlation coefficients for the linear relationship between heat production and weight

Overweight					Stocky and overweight combined			
Number of measurements	Weight range, kg.	Regression equation Y = Cal./hr. X = weight, kg.	Standard error of estimate	Correlation coefficient ³	Number of measurements	Regression equation Y = Cal./hr. X = weight, kg.	Standard error of estimate	Correlation coefficient ³
School Age to Puberty—Continued								
36	33.4–58.2	Y = 23.5 + 0.70X	4.3	0.74	81	Y = 27.6 + 0.63X	4.1	0.75
21	26.0–53.0	Y = 9.1 + 0.92X	4.8	.85	31	Y = 12.9 + 0.93X	7.7	.66
12	28.1–54.8	Y = 9.2 + 0.91X	3.5	.91	38	Y = 17.6 + 0.76X	3.7	.83
12	28.1–54.5	Y = 20.2 + 0.77X	4.2	.85	14	Y = 18.3 + 0.81X	3.9	.88
3	48.9–67.8	-----	-----	-----	13	Y = 25.2 + 0.70X	4.6	.77
16	34.1–59.6	Y = 35.6 + 0.42X	1.8	.85	43	Y = 28.5 + 0.56X	2.9	.85
27	42.3–63.6	Y = 27.6 + 0.65X	3.6	.80	61	Y = 24.5 + 0.71X	3.6	.85
Postpubertal to 16 years—Continued								
8	51.0–62.1	-----	-----	-----	15	Y = 23.2 + 0.61X	3.8	0.74
15	43.0–70.0	Y = 33.4 + 0.45X	3.5	0.66	24	Y = 39.5 + 0.36X	3.4	.64
14	41.5–57.4	Y = 21.5 + 0.59X	4.8	.55*	32	Y = 8.74 + 0.87X	5.8	.64
4	57.4–70.0	-----	-----	-----	15	Y = 21.5 + 0.64X	2.8	.81
23	52.8–72.9	Y = 32.6 + 0.50X	2.9	.58	73	Y = 38.5 + 0.40X	3.7	.47
6	47.7–67.6	-----	-----	-----	16	Y = 42.7 + 0.30X	5.6	.31 N.S.
12	51.0–64.1	-----	-----	-----	41	Y = 29.8 + 0.48X	5.9	.44
27	50.3–67.7	Y = 24.8 + 0.49X	4.3	.50	52	Y = 31.9 + 0.38X	5.2	.38
57	46.6–72.0	Y = 36.7 + 0.36X	5.2	.37	94	Y = 32.9 + 0.42X	4.8	.48
16 years and older—Continued								
16	44.0–62.4	Y = 5.7 + 0.86X	3.2	0.86	26	Y = 13.9 + 0.73X	4.8	0.62
18	53.2–73.9	Y = 19.0 + 0.67X	4.1	.67	40	Y = 23.6 + 0.59X	3.8	.71
27	54.4–66.2	Y = 26.2 + 0.56X	3.0	.49	47	Y = 26.7 + 0.56X	3.5	.59
40	47.2–73.5	Y = 29.8 + 0.37X	4.4	.46	103	Y = 33.3 + 0.31X	4.5	.39
26	47.9–73.1	Y = 19.1 + 0.64X	4.0	.76	47	Y = 18.4 + 0.65X	3.8	.77

³ Significant at the 1-percent level unless otherwise indicated: * = significant at the 5-percent level; N.S. = not significant.

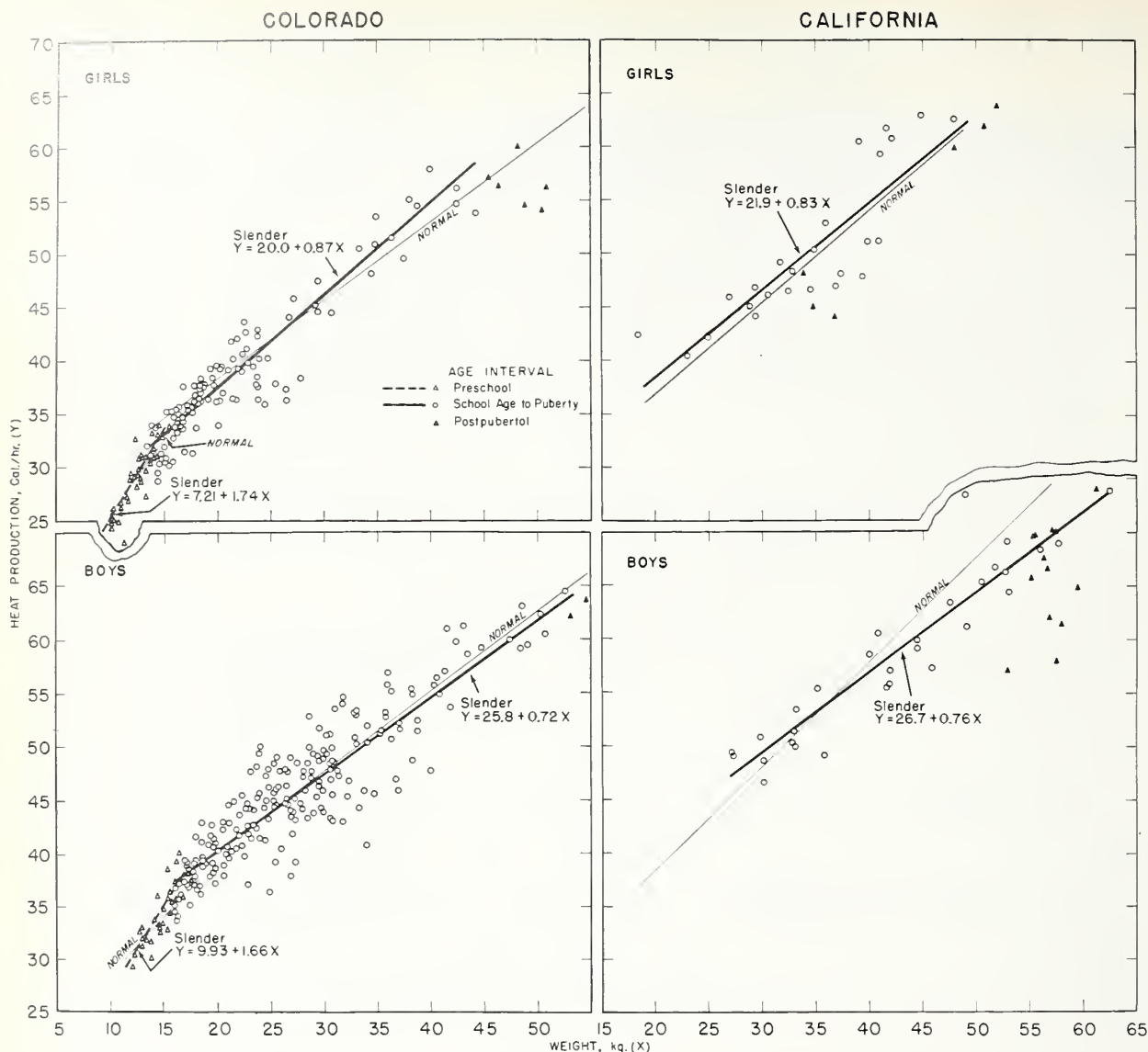


FIGURE 18.—COLORADO AND CALIFORNIA BOYS AND GIRLS WITHIN THE SLENDER WEIGHT-FOR-HEIGHT CLASSIFICATION: Relationship of basal heat production (Cal./hr.) to weight.

Individual data for the age intervals as indicated are shown and, when sufficient data are available, also the regression lines for each age interval. The regression lines (light lines) for children within the Normal weight-for-height classification are shown for comparative purposes. Data for Colorado children, from Lewis, Kinsman, and Iliff (1937) and Duval (1942); for California children, from Eichorn (n.p.).

others parallel, and in a few locations, are steeper than the regression lines for children within the Normal classifications.

Analysis of covariance (Snedecor, 1956) was used to determine whether the differences in slope and elevation of the regression lines for the different weight-for-height classifications were significant. The results, summarized in table 11, indicated that the slopes of the regression lines for children within the Normal and Stocky weight-for-height classifications and School Age

to Puberty age intervals were similar, but that in five of eight pairs there were significant differences in elevation. Although the difference was not statistically significant for two pairs (Taylor, girls; and Colorado boys), the elevation of the regression lines for the Stocky children was at a decidedly lower level than the corresponding regression line for children in the Normal weight-for-height classification (see figures 19 and 20). In another pair (Taylor, boys) the steeper slope of the regression line for the Stocky

TABLE 11.—BOYS AND GIRLS WITHIN THE STOCKY AND OVERWEIGHT WEIGHT-FOR-HEIGHT CLASSIFICATIONS: Summary¹ of results obtained from covariance analysis for comparison of the regression of heat production on weight

Location	Investigator(s) ²	Sex	Test for difference in slope ³			Test for difference in elevation ³		
			Between Normal and Stocky	Between Normal and Overweight	Between Stocky and Overweight	Between Normal and Stocky	Between Normal and Overweight	Between Stocky and Overweight
School Age to Puberty								
New York City	Taylor (n.p.)	Boys	N.S.	N.S.	N.S.	N.S.	(*)	(*)
Do	Topper and Mulier (1929a, 1932).	Girls	N.S.	N.S.	N.S.	N.S.	(**)	N.S.
New York	Davenport <i>et al.</i> (1939)	Girls	-----	(*)	-----	-----	(**)	-----
Colorado	Lewis <i>et al.</i> (1937); Duval (1942).	Boys	N.S.	N.S.	N.S.	(*)	(**)	(*)
California	Eichorn (n.p.)	Girls	N.S.	(**)	(**)	N.S.	(**)	N.S.
		Boys	(*)	(**)	(*)	(**)	N.S.	N.S.
		Girls	N.S.	N.S.	N.S.	(*)	N.S.	N.S.
Postpubertal								
New York City	Topper and Mulier (1929a, 1932).	Girls	-----	N.S.	-----	-----	(**)	-----
New York	Davenport <i>et al.</i> (1939)	Girls	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Michigan	Hoobler (n.p.)	Girls	(*)	N.S.	N.S.	N.S.	(**)	N.S.
Arizona	Thompson (n.p.)	Girls	-----	-----	-----	-----	-----	-----
Washington	Esselbaugh (n.p.)	Boys	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
California	Eichorn (n.p.)	Girls	N.S.	N.S.	N.S.	(*)	N.S.	N.S.
Boys 18 years and older; girls 16 years and older								
New York	Davenport <i>et al.</i> (1939)	Girls	-----	N.S.	-----	-----	(*)	N.S.
Ohio	McKay (1930)	Girls	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Michigan	Hoobler (n.p.)	Girls	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Arizona	Thompson (n.p.)	Boys	-----	-----	-----	(*)	N.S.	N.S.
California	Eichorn (n.p.)	Girls	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

¹ See tables 22, 23, and 24 (appendix B) for numerical values.

² For Literature References, see section XI.

³ N.S. = Not significant; * = significant at the 5-percent level; ** = significant at the 1-percent level.

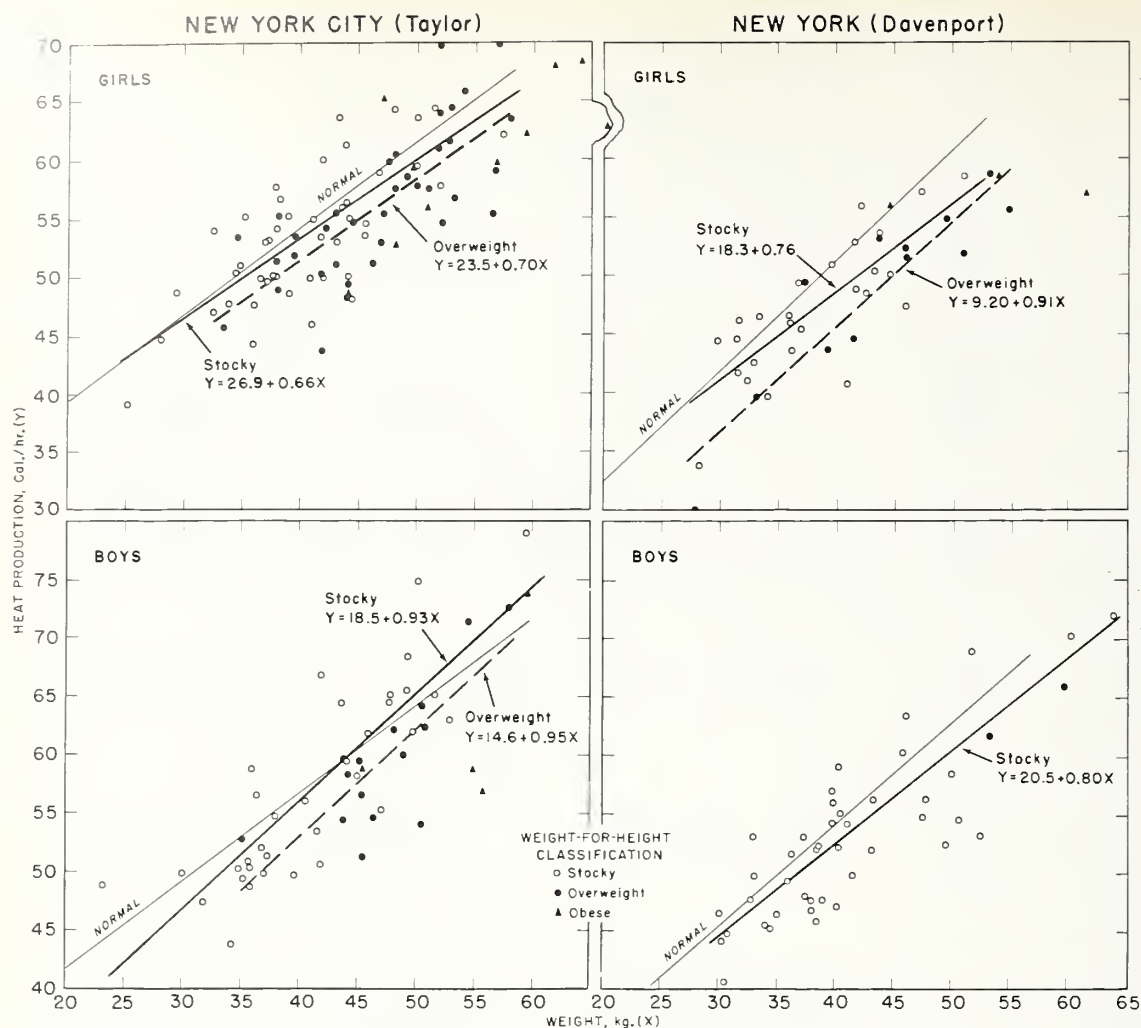


FIGURE 19.—NEW YORK BOYS AND GIRLS WITHIN THE STOCKY AND OVERWEIGHT WEIGHT-FOR-HEIGHT CLASSIFICATIONS AND SCHOOL AGE TO PUBERTY AGE INTERVAL: Relationship of basal heat production (Cal./hr.) to weight.

Individual data are shown and, when sufficient data are available, also the regression lines for each classification. The regression lines (light lines) for children within the Normal weight-for-height classification are shown for comparative purposes. Data from Taylor (n.p.) and Davenport, Renfro, and Hallock (1939).

children caused the regression lines to cross and, therefore, nullified any difference in elevation between the two.

In comparing the regression lines for the Normal and Overweight classifications, the differences in slopes were statistically significant for three of the eight pairs of boys and girls within the School Age to Puberty age interval. From an examination of the scatter diagrams (figure 20), it is considered that the significant differences obtained from 16 measurements on 4 Colorado girls and 16 measurements on 6 California boys cannot be attributed to real differences and should be discounted, because the flatter regression lines derived for these small groups on a few Overweight children were apparently due to high heat-production values at the lower end of the weight range. These high values were ob-

tained on children (for the Colorado girls, the 4 high measurements between 34 and 44 kilograms were on the same girl) who were adding weight out-of-proportion to their height; that is, they had either changed their weight-for-height classification from Stocky to Overweight or had become increasingly more overweight between measurements taken at 3- or 6-month age intervals.

Although the slopes were not significantly different statistically, some of the high heat-production values noted for the California girls (figure 20) can be similarly explained; that is, the girls were in the process of changing their weight-to-height relationships. From this examination of aberrant values for Overweight children, it is postulated that heat production may be greater for a child in the process of adding fatty tissue (changing the relationship between weight and

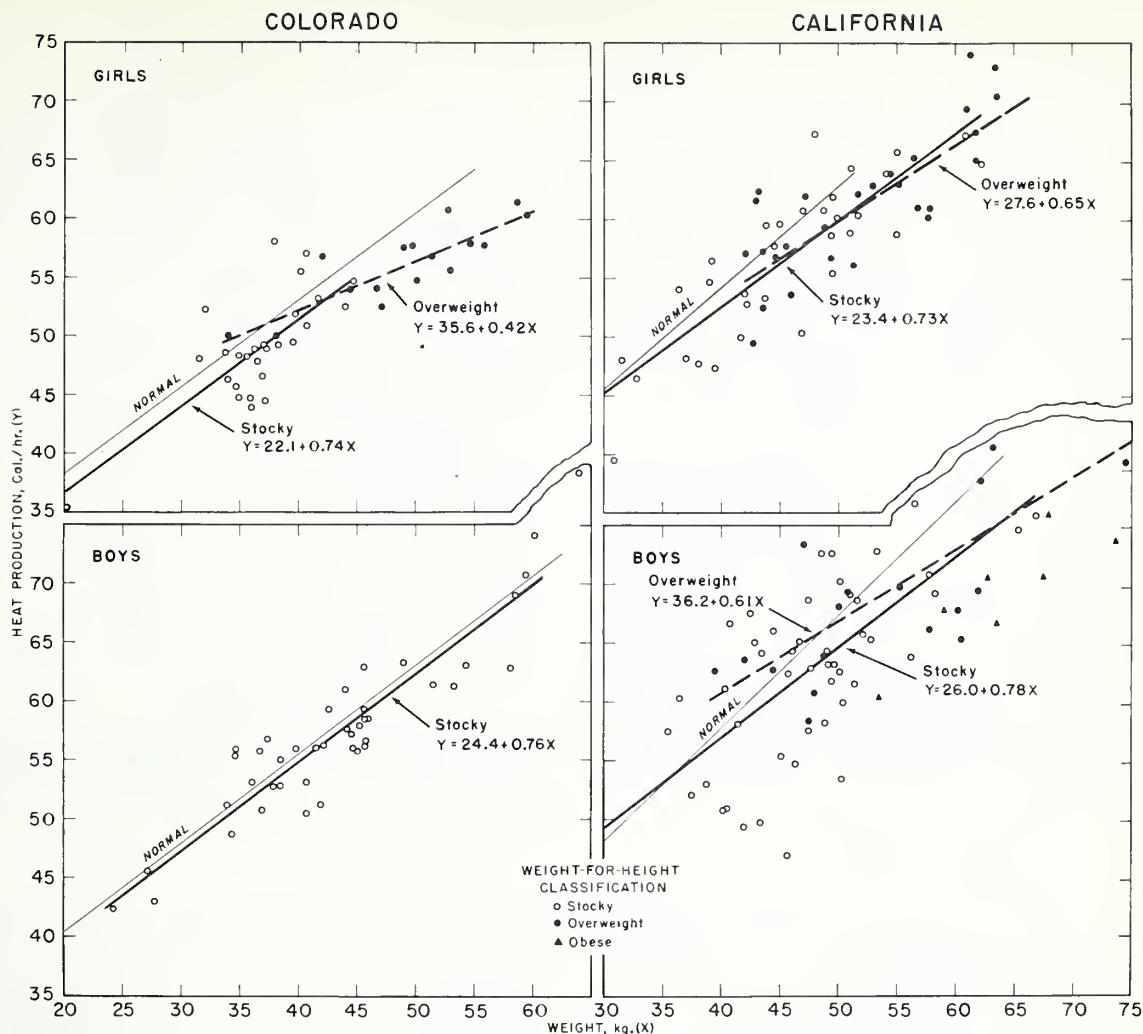


FIGURE 20.—COLORADO AND CALIFORNIA BOYS AND GIRLS WITHIN THE STOCKY AND OVERWEIGHT WEIGHT-FOR-HEIGHT CLASSIFICATIONS AND SCHOOL AGE TO PUBERTY AGE INTERVAL: Relationship of basal heat production (Cal./hr.) to weight.

Individual data are shown and, when sufficient data are available, also the regression lines for each classification. The regression lines (light lines) for children within the Normal weight-for-height classification are shown for comparative purposes. Data for Colorado children, from Lewis, Kinsman, and Iliff (1937) and Duval (1942); for California children, from Eichorn (n.p.).

height) than for a child who has been Overweight (maintaining the same relationship between weight and height) over a period of time.

The differences in elevation of the regression lines for Normal and Overweight weight-for-height classifications were statistically significant for six of the eight pairs of children within the School Age to Puberty age interval. The two pairs (California boys and girls) in which the differences in elevation were not significant should be discounted, since the difference in their slopes apparently nullified any difference in elevation and since the regression lines at the upper end of the weight range were decidedly lower for Overweight boys and girls than the respective regression lines for boys or girls within the Normal weight-for-height classification.

The differences between the slopes of the regression line for the Stocky and Overweight children within the School Age to Puberty age interval were not statistically significant with one exception—Colorado girls. This exception should be discounted since, as previously explained, the low slope of the regression line is believed to be caused by four high heat-production values obtained on one girl. The differences in elevation between the regression lines for Stocky and Overweight children were significant at the 5-percent level for two of the six pairs. Because of the limited number of measurements (12 and 15) available for deriving the equations for the Overweight girls reported by Davenport *et al.* (1939) and the Overweight boys reported by Taylor (n.p.) and also because in two pairs the differ-

ence between the elevations was less than the variation attributed to experimental error (variation about Common regression line, *see* appendix A, table 22), it is concluded that these differences must have been due to sampling variation.

The slopes of the regression lines for girls within the Postpubertal age interval and for girls 16 years and older (data for Postpubertal and older boys were insufficient for analysis) were not significantly different for any comparison between weight-for-height classifications with one exception, which was significant at the 5-percent level (*see* table 11 and figures 21 and 22). This finding is in agreement with the results from similar tests on the School Age to Puberty age interval.

For the Postpubertal and older girls, the differences in elevation between the regression lines for the Stocky and the Overweight girls were not significant for any pair. Significant differences in elevation were found between several of the pairs of Normal and Overweight girls and Normal and Stocky girls, but not as many as might be expected from the results of similar tests on girls in the School Age to Puberty age interval. However, the elevation of the regression lines for these Stocky and Overweight girls within the Postpubertal and older age intervals (shown in figures 21 and 22) were lower than the corresponding regression lines for the Normal girls,

although the differences were not statistically significant, probably due to the greater variation in heat production.

The conclusion from the data presented herein for the Stocky and the Overweight boys and girls within a given location is that heat production per unit of weight is the same (at least the difference is not statistically significant). Therefore, regression equations were derived from the combined data (*see* tables 9 and 10) and are the equations used for integration in section IX. For simplicity, these equations are referred to as the equations derived from data for children with the *Overweight* weight-for-height classification. Statistical tests indicated that, within a given location, the *slopes* of the regression lines for the Stocky and the Overweight children were similar to those for children within the Normal weight-for-height classification but that the *elevation* of the regression lines for the Stocky and the Overweight children were significantly lower than the regression lines for children within the Normal weight-for-height classification.

FOR UNDERWEIGHT AND OBESE CHILDREN

The group of Colorado girls (Lewis *et al.*, 1937, Duval, 1942) was the only one having sufficient measurements on Underweight children (22 meas-

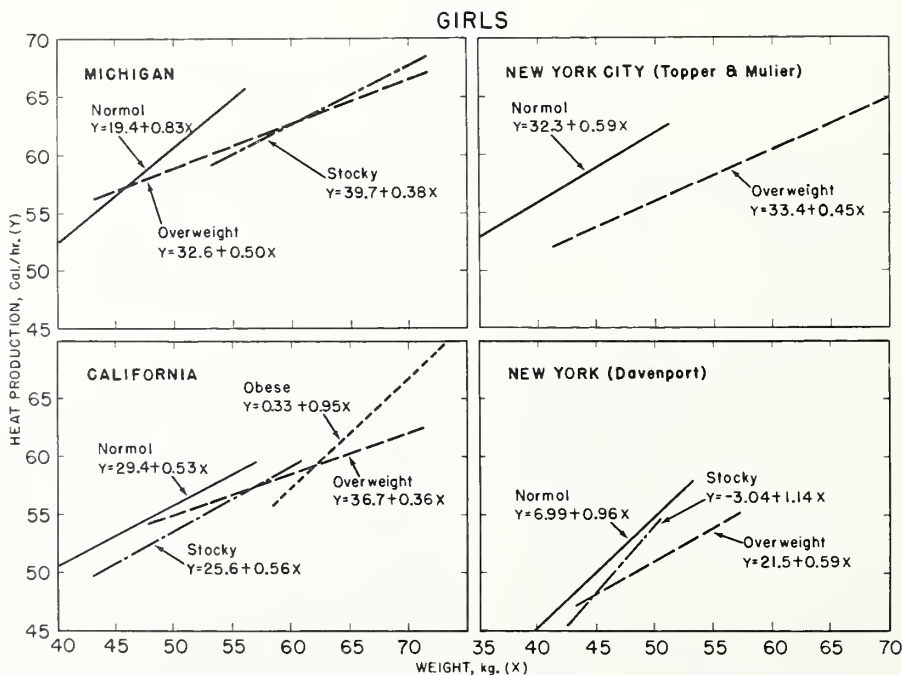


FIGURE 21.—POSTPUBERTAL TO 16-YEAR-OLD GIRLS: Regression lines showing the relationship between basal heat production (Cal./hr.) and weight for girls in different weight-for-height classifications.

Data for Michigan, from Hoobler (n.p.); for New York City, from Topper and Mulier (1929a, 1929b, 1932); for California, from Eichorn (n.p.); for New York, from Davenport, Renfroe, and Hallock (1939).

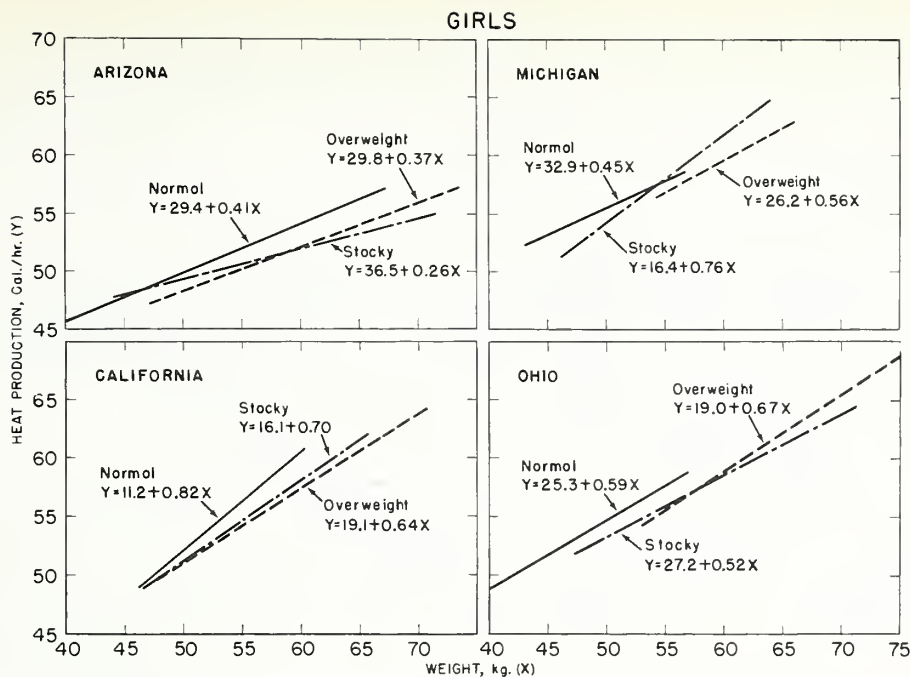


FIGURE 22.—GIRLS 16 YEARS AND OLDER: Regression lines showing the relationship between basal heat production (Cal./hr.) and weight for girls in different weight-for-height classifications.

Data for Arizona, from Thompson (n.p.) ; for Michigan, from Hoobler (n.p.) ; for California, from Eichorn (n.p.) ; for Ohio, from McKay (1930).

urements on 3 girls) and a weight range (13.8 to 35.9 kilograms) wide enough to derive an equation (see table 5). The results were as follows:

Heat production (Cal./hr.) =
 $24.2 + 0.68$ (weights, kg.), the correlation coefficient, 0.96; and standard error of estimate, 1.2 Calories.

The measurements on *Obese* children for any given location were few (see table 5); only two investigators reported data considered adequate for statistical analysis for both boys and girls within the School Age to Puberty age interval (see figure 23) and only one investigator (Eichorn, n.p.) reported sufficient measurements on Postpubertal girls (see lower left section of

figure 21). Statistical measures for the *Obese* children are given in table 12.

Figure 23 shows that the regression lines fitted to the data from Topper and Mulier (1929 a, 1932) for the *Obese* boys and girls are at a lower elevation and the slopes are somewhat flatter than the lines for the *Overweight* boys and girls, whereas the regression lines fitted to the data from Bruch (1939 a, 1939 b, 1942) for the *Overweight* and the *Obese* boys and girls are similar. Hence, further analysis of these data on the *Obese* children would be meaningless. The data indicate that the basal heat production per unit of weight for the *Obese* children approximates but may possibly be slightly lower than that for the *Overweight* children.

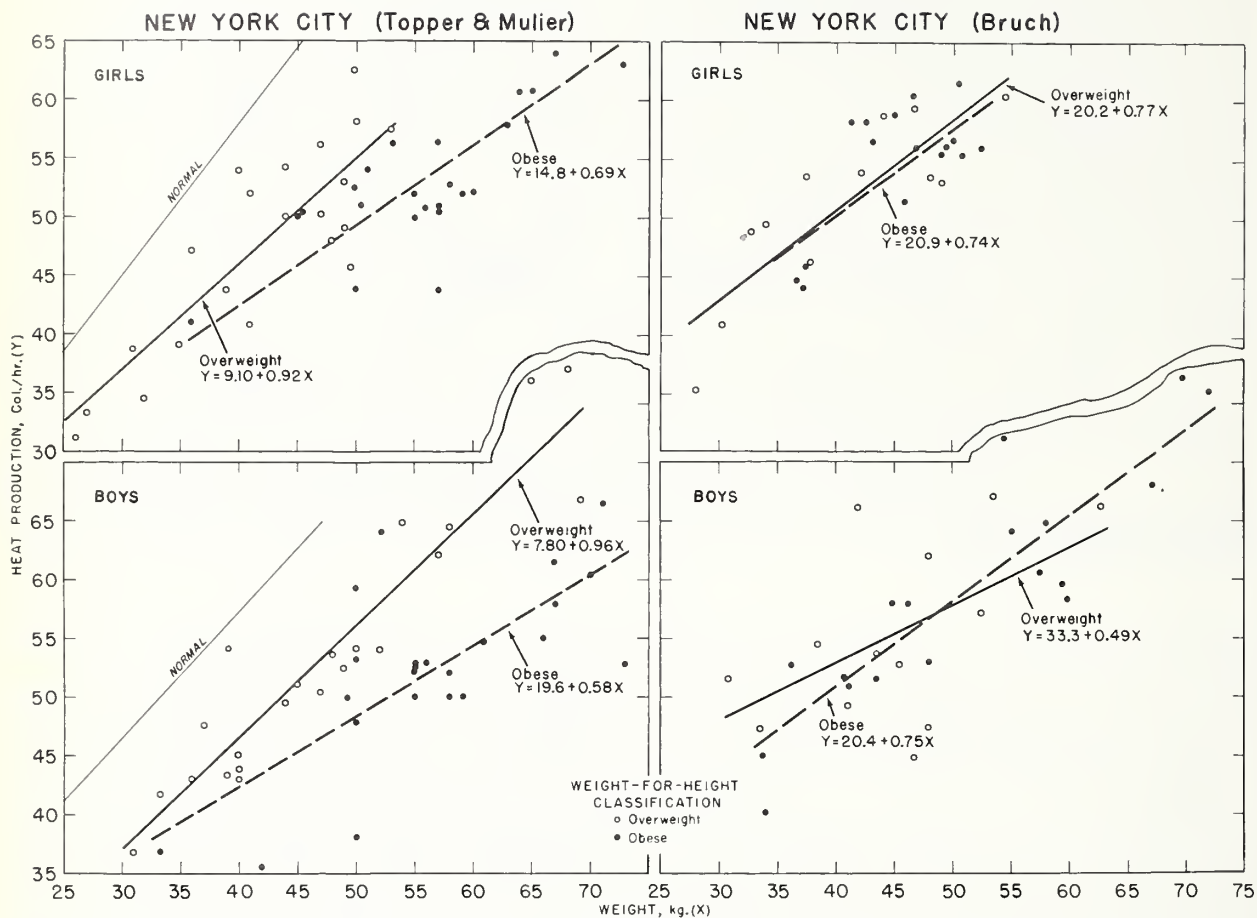


FIGURE 23.—NEW YORK CITY BOYS AND GIRLS WITHIN THE OVERWEIGHT AND OBESE WEIGHT-FOR-HEIGHT CLASSIFICATIONS AND SCHOOL AGE TO PUBERTY AGE INTERVAL: Relationship of basal heat production (Cal./hr.) to weight.

Individual data along with the regression lines are shown for Overweight and Obese children; the regression lines (light lines) for children within the Normal weight-for-height classification are shown for comparative purposes for the data from Topper and Mulier (1929a, 1929b, 1932). The data from Bruch (1939a, 1939b, 1942) did not include children in the Normal weight-for-height classification.

TABLE 12.—OBESE BOYS AND GIRLS: *Regression equations,¹ standard errors of estimate, and correlation coefficients for the linear relationship between heat production and weight*

Location	Investigator(s) ²	Sex	Number of measurements	Weight range, kg.	Regression equation Y = Cal./hr. X = weight, kg.	Standard error of estimate	Correlation coefficient ³
New York City Do-----	Topper and Mulier (1929a, 1932). Bruch (1939a, 1939b, 1942).	School Age to Puberty					
		Boys	23	33. 0-73. 0	Y=19. 6+0. 58X	5. 9	0. 69
		Girls	24	36. 0-79. 0	Y=14. 8+0. 69X	4. 0	. 83
		Boys	18	33. 8-72. 1	Y=20. 4+0. 75X	4. 8	. 89
		Girls	16	36. 7-52. 4	Y=20. 9+0. 74X	3. 9	. 71
		Postpubertal to 16 years					
California-----	Eichorn (n.p.)-----	Girls	21	58. 1-78. 0	Y=0. 33+0. 95X	6. 1	0. 71

¹ Equations were not derived for locations having less than 12 measurements and a weight range of less than 15 kg. within a given weight-for-height classification.

² For Literature References, see section XI.

³ Significant at the 1-percent level.

VIII.—Analysis of Problems Encountered

A.—PROBLEMS PERTAINING TO METHODS OF MEASURING OXYGEN CONSUMPTION

Tables 6 and 7 in the preceding section showed that the equations expressing the relationship between heat production and weight for a given weight-for-height classification and age interval differed for the locations within any geographical region. These differences may be due to the following: (1) Type of apparatus; (2) whether the children were inexperienced, experienced, or extensively "trained" in having a basal metabolic measurement; and (3) the selection of a value for reporting basal metabolic measurements when more than one test was made. These variable factors are interrelated to a certain extent and since the method and procedures followed by the investigators were seldom identical except for one variable (table 13), separate analyses for any one variable cannot always be made. Therefore, before an attempt is made to integrate the data, these differences are discussed and conclusions drawn as to whether they cause appreciable differences in heat production.

Types of Metabolic Apparatus

The principles, procedures, and calculations involved in determining heat production indirectly by both the open-circuit and the closed-circuit types of apparatus have been reviewed by many authors (for example, *see* Du Bois, 1936; Lewis *et al.*, 1943a; Brody, 1945). The size of the apparatus may be varied for each type from the elaborate respiration-chamber type to the more simple spirometer type employing a helmet, mask, or mouthpiece and nose clip. It appears that most investigators agree with Lewis *et al.* that "when extreme care is taken to have the subject in a postabsorptive condition, well relaxed, and with muscular activity cut to a minimum, the observation of careful technique will ensure determinations that will be a true measure of the basal metabolism regardless of which type of apparatus is used," or, as stated more simply by Du Bois, "most of the errors lie, not in the machines, but in those who operate them."

However, the closed-circuit type is thought by some (Boothby *et al.*, 1936; Fowler *et al.*, 1957) to be less reliable than the open-circuit for a number of technical reasons.

(1) The R.Q. (respiratory quotient) is assumed rather than measured; thus, introducing a possible error. Boyd (1954) estimated the error due to this assumption to be less than 0.6 percent. Robertson (1937) also thought this error of no practical consequence and presented the opinion that by using a R.Q. of 0.82, "a correction rather than an error is being introduced in the calculations for the chances are that the measured R.Q. in a short-period experiment of 10 minutes is fallacious."

(2) A small leak around the mouthpiece or mask causes a large error in the closed-circuit type but only a small one in the open-circuit (Du Bois, 1936; Fowler *et al.*, 1957).

(3) A possible change in the average level of the "reserve" or "supplementary" respiratory volume of a subject under test causes deceptive results by the closed-circuit system (Boothby *et al.*, 1936; Willard and Wolf, 1951). Roth and Buckingham (1939) pointed out that this problem is rarely encountered under the controlled conditions of metabolic testing and that if these changes did occur, the graph would probably reveal such; nevertheless, they made suggestions to prevent such errors. Any change in respiratory volume is probably associated with apprehension (Willard and Wolf, 1951).

(4) Personal judgment or prejudice may enter into estimating the slope of the oxygen consumption line from the spirogram (Boothby *et al.*, 1936).

A close agreement between results obtained from the open-circuit and closed-circuit methods of measuring heat production was found by Robertson (1937) from determinations made on the same subject tested alternately for 10-minute periods with the Douglas bag and Benedict-Roth apparatus; by Willard and Wolf (1951) from determinations made on trained subjects the same day, using the Tissot spirometer and the Benedict-Roth apparatus; and by Lewis *et al.* (1943a) from determinations made on 36 children (65 determinations) and 25 adults (55 determinations), using the open-circuit chamber immediately preceding or following a determination made with a McKesson Metabolor. Fowler *et al.* (1957) also found that consecutive tests by the two methods did not differ significantly, although the basal metabolic rate (calculated from the 1936 Mayo Foundation Standards) obtained by the two methods differed by more than 5 percent in 21 of the 48 cases.

TABLE 13.—Types of apparatus and procedures used to obtain basal metabolic data and the corresponding statistical measures

[From data on children within the Normal weight-for-height classification and School Age to Puberty age interval.]

Investigator(s) ¹	Child's experience with test procedure ²	Selection of tests for reporting "basal" ³	Number of test days	Number of measurements		Regression of heat production on weight						Estimated heat production, Cal./hr. when weight = 35 kg.	
						Regression coefficient		Standard error of estimate, Cal./hr.		Correlation coefficient			
						Boys	Girls	Boys	Girls	Boys	Girls		
Open-circuit method (chamber was used by Colorado; mask used by others)													
Lewis <i>et al.</i> (1937); Duval (1942).	Inexperienced children usually required a training period. Two trial tests made before experimental series began.	One satisfactory test.	---	736	457	0.74	0.78	2.8	2.5	0.90	0.92	51.3	49.5
Eichorn (n.p.)	Mean of all tests made	(6)	2	298	111	.92	.83	3.7	3.4	.89	.82	53.0	50.1
Morse (n.p.) ⁴ Maroney and Johnston (1937).	Inexperienced Inexperienced	Mean of all tests (3) Not reported	1 (?)	---	22 13	---	1.30 .85	2.0	4.0 3.4	---	.82 .82	---	49.1 50.8
Closed-circuit method													
Lamb (n.p.)	"Trained"	Mean of tests within 5%. Lowest (from 4)	At least 2. 2	22 171	21 130	0.74 .86	0.66 .95	1.6 4.1	2.4 3.7	0.96 .86	0.78 .88	50.4 49.8	47.2 46.7
Davenport <i>et al.</i> (1939) Topper and Mulier (1929a, 1929b, 1932). Webster <i>et al.</i> (1941)	Inexperienced for first measurement. Inexperienced for first measurement. Inexperienced for first measurement. "Dummy" test made on preceding day.	Lowest (from 4) Mean of tests which checked (2). Mean of tests within 5%.	1(?) 1 At least 2.	39 70 135	57 32 150	1.02 .89 .75	1.39 1.09 .76	3.2 4.4 3.5	4.2 3.9 3.6	.93 .83 .82	.90 .83 .83	51.7 53.5 52.8	52.9 50.5 50.4
Talbot <i>et al.</i> (1937) Thompson (n.p.)	Inexperienced Inexperienced	Mean of tests within 5%. Mean of tests within 5%.	At least 2(?) At least 2.	---	16 28	---	1.29 .73	---	7.3 3.5	---	.75 .77	---	50.9 49.2
Morse (n.p.) ⁴ Harrison (n.p.) Esselbaugh (n.p.) Hoobler (n.p.)	Inexperienced Inexperienced Inexperienced Inexperienced for first measurement.	Mean of all tests (3) Mean of all tests (4) Mean of all tests (2) Mean of all tests	1 2 1 1 or more	83 41 40	41 34	.90 .79 .99	.82 .99	5.0 5.8 3.8	3.2 3.3	.86 .55 .86	.81 .94	53.8 51.7 56.3	52.1 53.8
Open-circuit and closed-circuit (Benedict's cot-chamber) combined													
Wang (1934, 1939); Wang <i>et al.</i> (1926, 1936).	Preliminary training tests made.	Lowest (from 6)	3	14	40	81	0.65	3.1	2.5	0.84	0.91	53.8	49.5

¹ For Literature References, see section XI.² Assumed to be inexperienced unless otherwise specified.³ See table 2 for further details.⁴ All the measurements on the girls were made by open-circuit (Douglas bag); more than 80 percent of the measurements on the boys were made with the closed-circuit method.

It appears that, although the results reported for the two methods are in agreement, the disagreement occurs in the interpretation of the results. In comparing the two methods, a correlation coefficient of 0.84 was interpreted by Fowler *et al.* (1957) as indicating that a correlation was "present but not close;" whereas correlation coefficients of 0.94 for children and 0.81 for adults were considered by Lewis *et al.* (1943a) to show "excellent correlation between the two methods both for children and for adults."

Because statistical measures other than the correlation coefficient need to be considered in interpreting results when the two methods are being compared, and since it is believed that actual values obtained should be used instead of calculated values, such as the basal metabolic rate (percentage deviation from some specified standard) or heat production in terms of per unit of body surface, the data reported by Lewis *et al.* (1943a) on children were recomputed on the basis of Calories per hour. The 65 determinations obtained by the closed-circuit method were used to represent the *Y*-axis and the corresponding determination obtained by the open-circuit chamber, the *X*-axis. The equation comparing the two methods was $Y=1.02+0.98X$, the standard error of estimate, 1.8 Calories, and the correlation coefficient, 0.98. Values closer to a perfect agreement between the two methods could not be expected from basal metabolic data.

Further analysis of the data of Lewis *et al.* (1943a) was made by separating the data obtained by the closed-circuit method into the determinations made by using the usual mouthpiece and nose clip from those made with a mask. When paired and correlated with the determinations obtained on the same morning by the open-circuit method, the difference between the two was insignificant—the use of the mask or mouthpiece and nose clip was equally satisfactory. However, Wilbrecht (1948) reported that apprehension and fear were less with the mask than with the nose clamp.

As shown in table 13 the standard error of estimate about the regression line is approximately the same regardless of the type of apparatus used. However, other factors influence the variability, and since the procedures followed by any two investigators were not identical, except for the type of apparatus, the data are not comparable. Our conclusion, therefore, must be based upon reports from the literature and from the evidence gained from the foregoing analysis of the data obtained from consecutive determinations, using both types of apparatus as reported by Lewis *et al.* (1943a). We consider that the open-circuit and closed-circuit types of apparatus are equally satisfactory and that the type of apparatus need not be considered a variable in analyzing these data.

Subject's Experience With the Test Procedure

The accepted conditions for basal metabolic measurements have been standardized, in that the subject should be in post-absorptive condition (at least 12 hours after the last food intake): have a normal body temperature; have muscular and mental repose; and have a preliminary rest period of 20 or 30 minutes before the test. Adequate training, or familiarity with the apparatus and with the procedure followed, especially for young children, is an additional criterion recommended by some (Shock, 1942; Vogelius, 1945; Keys *et al.*, 1950; Hawk *et al.*, 1954), but is by no means standardized (see table 2).

Thus, basal metabolic values sometimes are based on the first test obtained from inexperienced subjects (Boothby *et al.*, 1936; Eaton, 1939) and sometimes are based on tests obtained from subjects "thoroughly trained" in the procedure of having basal metabolic determinations (Lamb, 1945; Lamb and Michie, 1954). Usually, however, the values are based on tests in which the subjects have had some preliminary experience with the test procedure before the actual determination (Wang *et al.*, 1926, 1936; Wang 1934, 1939; Lewis *et al.*, 1937, 1943; Shock, 1942; Garn and Clark, 1953), or the tests are repeated on successive days until a set agreement between tests is reached (McKay, 1930; Molitch and Cousins, 1934; Lewis, 1936; Talbot *et al.*, 1937; Robertson and Reid, 1952; Thompson *et al.*, 1948), or until a stabilization is reached (Biering, 1931; Vogelius, 1945), so that any high tests attributable to inexperience may be discarded.

Marked individual differences in adaptation to the testing procedure of measuring oxygen consumption have been observed by many. From measurements on postpubertal girls from the Hebrew Orphan Asylum, Lewis (1936) observed that "there was considerable variation among persons in the consistency of successive determinations. Some subjects gave results which were always within a small percentage of each other, even when the tests were well spaced in time; others gave a wide range of values, and the checks finally obtained for the group were on the whole less satisfactory than for the 'constant' subjects . . . After a careful and systematic review of all the material collected . . . there remained about 13 (of 50) subjects for whom some figures had been obtained which varied more than 10 percent from their lowest value and which could not be explained on the basis of an observed or inferred non-basal relaxation."

Vogelius (1945) also found that the amount of training necessary for oxygen consumption to become stabilized varied greatly from person to person and that the adaptation to the technical procedure sometimes was very slow; of 150 girls

measured, at least 30 had considerable difficulty in adapting to the procedure.

From observations on the nursery-school children in Texas, Ling (1946) reported that each child underwent 8 to 9 stages of adaptation to become "thoroughly trained" to the basal metabolic conditions; the number of trials ranged from 11 to 23, but not a single child "failed to pass the test." Lamb and Michie (1954) reported that at the time of the actual determination these children were "cooperative, willing, and capable in following the details of the procedure."

Whether the first test on a child is high because of inexperience cannot be known unless additional tests are made for comparison, even though tests in which the child was obviously restless or under nervous tension are eliminated. As Bierring (1931) aptly stated "many children during the first experiments, although apparently in complete muscular repose, in reality are in a state of excessive hypertoni. This is not always due to anxiety or agitation but may also be caused by the fact that the child, zealous not to make any movements, immobilizes the articulations by contracting the muscles." Jackson (1957a) also pointed out that "even under ideal conditions it may be necessary to repeat the test one or more times before it can be considered accurate."

Webster *et al.* (1941) and Thompson *et al.* (1948) reported that the first test on about half of their subjects was found to be appreciably higher than subsequent tests. Robertson (1944) found from observations on 223 young nurses, who had volunteered for the test, that in 70 percent the initial readings were higher than those on the second day; in 42 percent, they were higher by 10 percent or more. Lewis *et al.* (1944) reported that only 35 percent (of 94 children) gave "satisfactory" results on the first determination. However, from results on 26 children having satisfactory tests on the first determination, they concluded that "no significant difference could be attributed to experience" when the first determination was compared with that of a repeated test at an older age on the basis of deviation from the standard values. It must be recognized that this conclusion was based on a selected group consisting of about one-fifth of the total group measured and represents those children most cooperative and adaptable to the experimental procedure.

From the available data on individual tests reported herein, the average of the tests (two or three) on the first and on the second mornings were compared. Only values obtained during the first measurement period (earliest age measured) for a given child were used to represent "inexperienced" children and children having preliminary or "dummy" tests before the actual measurement period. For the "experienced" children the tests for all the measurements reported by Lamb (n.p.) on "trained" children were used, as

were the tests for all measurements except the first measurement for each child from the longitudinal study of Eichorn (n.p.). Since Vogelius made tests for a minimum of three mornings, it was possible to use his data twice: (1) By using the first morning's tests for "inexperienced" girls; and (2) by discarding the first morning's tests, considering the girls as being "experienced" with the test procedure, and comparing the tests made on the second morning with those made on the third morning.

The percentages of the total number of children whose average test on the first morning (or the second morning for Vogelius' "experienced" girls) was at least 5 percent higher than the average on the second morning (or the third morning for Vogelius' "experienced" girls) were as follows:

	Boys Percent	Girls Percent
Inexperienced children:		
Arizona (Thompson, n.p.)-----	28. 0	26. 4
Kansas (Harrison, n.p.)-----		23. 8
Vogelius (1945)-----		36. 5
Children having preliminary or "dummy" tests prior to meas- urement:		
New York City (Taylor, n.p.)----	19. 6	18. 6
California (Eichorn, n.p.)-----	15. 5	33. 8
Experienced or trained children:		
California (Eichorn, n.p.)-----	12. 6	16. 7
Texas (Lamb, n.p.)-----	10. 2	12. 8
Vogelius (1945)-----		15. 2

These results are somewhat lower than those previously cited from the literature, probably because they are based on the average of duplicate (or triplicate) tests made on the first test morning, whereas in the references cited, it is presumed that only the initial first test was considered. The percentage of children whose tests on the first morning were at least 5 percent higher than those on the second morning declines with experience. The practice of preliminary or dummy tests before the actual measurement is advantageous, in that it lowers the percentage of children having high tests on the first day but does not lower it to the extent that repeated testing or training does.

Since the procedure followed by Lamb (n.p.) and Taylor (n.p.) were essentially the same (table 13), except for the amount of experience on the part of the children, the percentage of subjects returning for a third day of testing in order to obtain a 5-percent agreement was calculated. For the "trained" children (Lamb, n.p.) this was about 10 percent, whereas for the children having a "dummy test" before the actual basal metabolic measurement period (Taylor, n.p.), it was about 35 percent.

Du Bois (1936) estimated that basal metabolism was about 5 percent higher for untrained subjects, and Vogelius (1945) found that the first test for 150 girls averaged 8 percent higher than the mean of the "last determinations." Whether the average basal metabolic value for a group is

significantly higher when the first test on inexperienced subjects is included will depend upon the basis of comparison, that is, upon the selection of a value(s) for computing the "final" result. These comparisons will be made in the following subsection.

From the foregoing discussion, it is concluded that experience with the test procedure is usually essential in order to obtain a reliable measurement. Because of individual differences in the amount of training required to insure that a subject is in complete mental and muscular repose, no set rule can be adopted as to how much experience should be required. It is recommended, however, that preliminary tests (which need not be made under post-absorptive conditions) be given to inexperienced subjects in order to familiarize them with the apparatus and thus promote relaxation. Although additional experience will be required to obtain reliable measurements on some subjects, a preliminary testing period probably will be adequate to insure a satisfactory measurement on most subjects and will eliminate some testing on all subjects.

Methods Used in Selecting Values for Reporting Basal Metabolic Data

As shown in table 13 (*see* also table 2) the values selected by the various investigators for reporting basal metabolic measurements were not consistent. Whether these various methods of selection have caused the results from one investigator to be significantly different from those of another is the problem under consideration. Since data for individual tests were made available from several unpublished sources, it was possible to compare the results computed by several methods.

Regression equations and other statistical measures computed by several methods are given in table 14, along with the method selected by the investigator for reporting results. Similar results were obtained for all methods, although the correlation coefficients were usually lower and the standard errors of estimate larger when the first tests were used than for the other methods of computation.

The slopes of the regression lines were parallel for all methods. This is obvious from figure 24, but was confirmed by statistical tests, in which the variation attributed to the differences among slopes was less than the pooled variation from individual regressions for all locations, with one exception. For the slopes derived from the data for California girls from Eichorn (n.p.) a small but insignificant difference was obtained between the slopes derived by the two methods.

The regression lines, although parallel, were at several elevations, depending upon the method of computation. To determine whether these differences in elevation were statistically significant,

statistical tests were made between the methods of computing results. The difference in elevation between the regression lines for the lowest test and the mean of all tests was significant for all seven pairs (from five locations). The differences in elevation between the regression lines for the lowest test and the mean of selected tests (usually those tests within 5 percent), and also for the mean of all tests and the mean of selected tests, were not statistically significant for any pair. The slight differences in elevation among the regression lines derived from the first test, from the mean of all tests, and from the mean of selected tests were not significant, with the exception of the data from Vogelius (1945). In his report the regression line for the first test was significantly higher (in elevation) than that for the mean of all tests.

These results indicate that no significant difference in elevation of the regression lines can be attributed to the methods of selecting and/or computing the basal metabolic data, except between the mean of all tests and the lowest test. Therefore, locations using all tests for reporting basal metabolic values may be comparable to locations using methods of selection other than the lowest test only. Locations reporting values computed from the tests agreeing within 5 percent may be comparable with locations using the lowest test.

Objections to using the lowest test (or the mean of the lowest values) to represent a basal metabolic value are (1) because it "vitiates the advantage gained in accuracy of the mean values of individual measurements that are each subject to random errors" (Fowler *et al.*, 1957); and (2) because of individual differences in adaptation to the procedure, the lowest of a specified number of tests may not be comparable for all subjects unless the method of Bierring (1931) and Vogelius (1945) was followed (table 1).

It is recommended that the mean of all tests (with exception of extreme values) be used for reporting basal metabolic data, providing that the subject has had preliminary tests before the actual measurement period, since (1) heat production, like other biological processes, is a variable quantity even under standardized conditions, and (2) the results based on the mean of all tests were not significantly different from the results based on the mean of tests agreeing within 5 percent.

From the foregoing discussion it is concluded that the *slopes* of the regression lines for the relationship of heat production to weight are comparable for children within a given age interval and weight-for-height classification, and that any difference in *slope* is due to some factor other than apparatus, procedure, or experience of the child in having oxygen consumption measured. However, the *elevation* of the regression line will vary in accordance with experience of the sub-

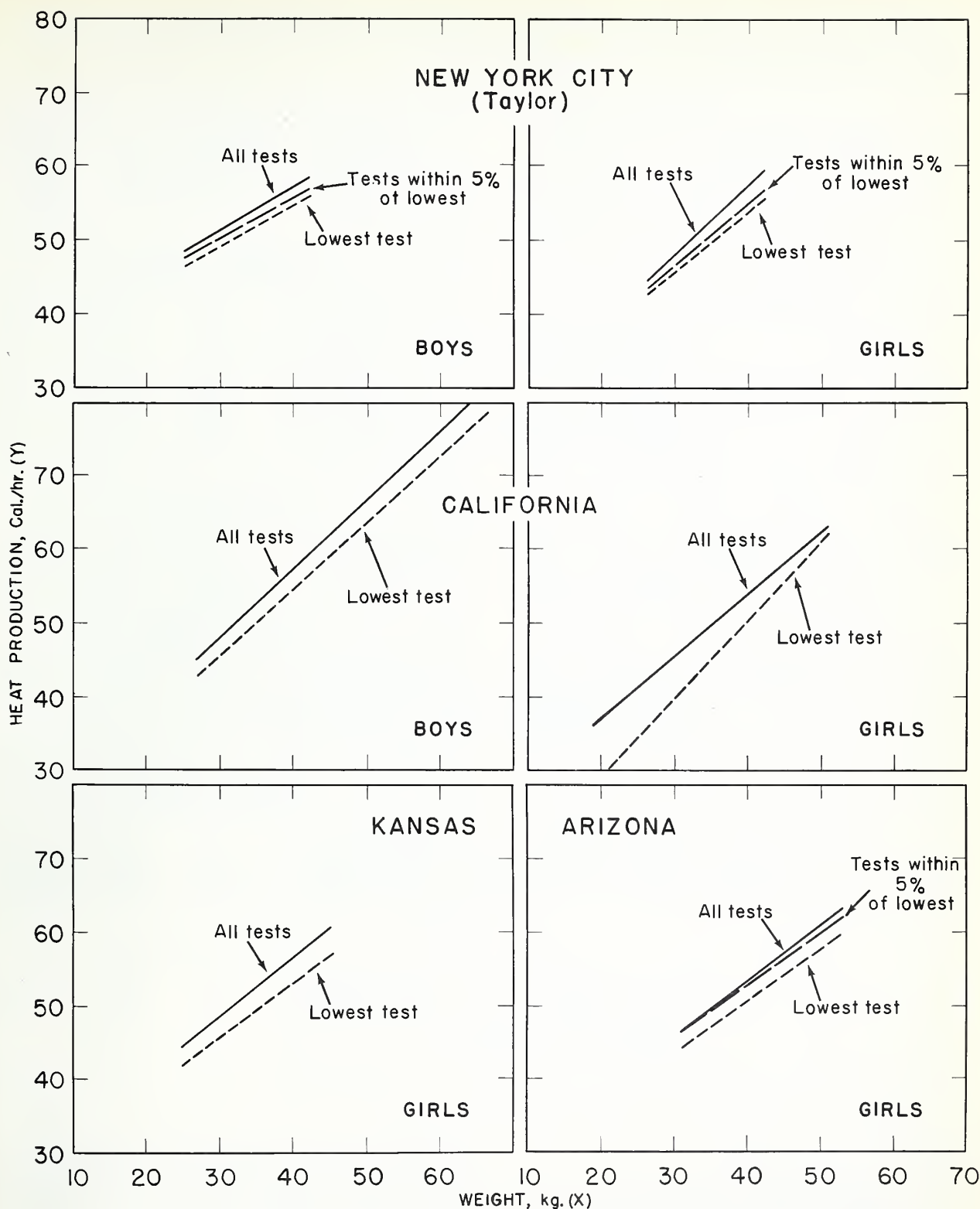


FIGURE 24.—VARIOUS METHODS USED IN SELECTING VALUES FOR REPORTING BASAL METABOLIC MEASUREMENTS: Regression lines relating basal heat production to weight.

From data for children within the Normal weight-for-height classification and School Age to Puberty group. Data for New York City, from Taylor (n.p.) for 9- to 11-year-old children only; for California, from Eichorn (n.p.); for Kansas, from Harrison (n.p.); and for Arizona, from Thompson (n.p.). See table 14 for equations.

TABLE 14.—Regression equations obtained by various methods used in reporting basal metabolic measurements

[From data on children within the Normal weight-for-height classification and School Age to Puberty age interval.]

Sex	Number of measurements	Weight range, kg.	Method	Regression equation Y=Cal./hr. X=weight, kg.	Standard error of estimate	Correlation coefficient	Estimated heat production, Cal./hr., when weight =40 kg.
New York City (Taylor, n.p.) ¹							
Boys-----	53	25. 7-41. 8	First test----- Mean of all tests (at least 4)--- Mean of tests within 5% of lowest (at least 3).	Y=30.3+0.71X Y=34.5+0.57X Y=33.0+0.58X	4. 8 3. 0 2. 9	0. 49 . 58 . 59	58. 5 57. 3 56. 0
Girls-----	50	26. 0-42. 4	Lowest----- First test----- Mean of all tests (at least 4)--- Mean of tests within 5% of lowest (at least 3). Lowest-----	Y=31.9+0.58X Y=19.4+0.97X Y=19.0+0.97X Y=21.2+0.85X Y=20.7+0.84X	3. 0 5. 2 3. 8 3. 8 3. 6	. 59 . 62 . 73 . 69 . 70	55. 0 58. 0 57. 7 55. 3 54. 3
Kansas (Harrison, n.p.)							
Girls-----	29	25. 1-44. 5	Mean of all tests (4)----- Lowest-----	Y=23.5+0.83X Y=22.9+0.76X	3. 2 3. 4	0. 82 . 78	56. 6 53. 1
Arizona (Thompson, n.p.)							
Girls-----	21	30. 8-52. 8	First test----- Mean of all tests (at least 4)--- Mean of tests within 5% of a selected test. Lowest-----	Y=19.8+0.84X Y=22.7+0.76X Y=23.4+0.73X Y=21.5+0.72X	5. 2 4. 1 3. 8 4. 1	0. 69 . 74 . 75 . 73	53. 6 53. 1 52. 7 50. 5
California (Eichorn, n.p.)							
Boys-----	268	27. 4-65. 2	Mean of all tests (6)-----	Y=19.5+0.95X	3. 8	0. 89	57. 7
	251	28. 3-65. 2	Lowest-----	Y=17.3+0.93X	4. 4	. 85	54. 6
Girls-----	86	19. 5-51. 4	Mean of all tests (6)-----	Y=19.7+0.86X	3. 4	. 80	54. 1
	75	28. 4-51. 4	Lowest-----	Y=6.7+1.09X	4. 7	. 75	50. 4
Denmark (Vogelius, 1945)							
Girls-----	59	20. 8-47. 0	First test----- Mean of all tests (at least 6)--- Mean of tests which did not show a falling tendency (at least 4). Lowest-----	Y=22.2+0.89X Y=20.0+0.88X Y=19.1+0.88X Y=18.5+0.87X	3. 9 2. 7 2. 8 2. 8	0. 82 . 90 . 90 . 90	57. 7 55. 3 54. 3 53. 3

¹ For 9- to 11-year-old children.

ject and with the selection of a value(s) for computing the results reported.

B.—PROBLEMS PERTAINING TO METHODS OF ANALYZING DATA

Further analysis of data for children within the Normal weight-for-height classification and School Age to Puberty age interval were made to

answer pertinent questions which arose while the foregoing regression equations were being derived. The findings are presented here to aid the readers who may have similar questions regarding these data. The longitudinal data from Lewis *et al.* (1937) and Duval (1942), from Eichorn (n.p.), and, to a lesser extent, from Davenport *et al.* (1939) were used for these analyses.

Regression Lines Relating Basal Heat Production to Weight for Cross-Sectional and Longitudinal Data

In section VII the longitudinal data were analyzed the same as were the cross-sectional data; that is, each measurement was treated separately. However, in this procedure overemphasis is given to data obtained from repeated measurements on the same children. Thus, the data may not be representative of the normal population group being studied. This objection may be valid when many measurements are made on a few subjects and each measurement is given equal consideration in a small group of otherwise cross-sectional data. However, in this report nearly all children were measured repeatedly in large groups of longitudinal data, and no one child predominated any group in the Normal weight-for-height classification.

In table 15 are presented the number of children in relation to the number of measurements for our major sources of longitudinal data. Although the published data of Topper and Mulier (1932) consisted of periodic measurements made on adolescent boys and girls, the data when separated into age intervals could not be considered longitudinal, since only one or two measurements per subject were represented within the School Age to Puberty age interval.

In order to compare the regression equations derived from cross-sectional data with the equations derived from longitudinal data, one measurement per child was selected at random (or as near random as the data permitted to provide representation of all possible ages and weight) from the longitudinal data from three investigators. The regression equations derived from these "cross-sectional" data are in excellent agree-

ment with those derived in section VII on the longitudinal data, as shown in figure 25.

Regression Lines Relating Basal Heat Production to Weight for Individual Children and for Many Children

The measurements on Colorado children (Lewis *et al.*, 1937; Duval, 1942) were made over a period of 9 years, thus making it possible to obtain regression lines relating heat production to weight for individual children. The lines shown in figure 26 were fitted to the data by inspection for children having measurements for the longest age span. Although the slopes of the regression lines for *individual* children were sometimes steeper and sometimes flatter than those derived from data for *many* children of different ages, the regression lines were similar. Thus, it appears that the derived equations from data for many children are applicable to individual children. The regression lines for individual children might be altered slightly if data were available on the same child throughout the entire age span of 4 or 4½ years to puberty as represented by the regression equation for many children.

Regression Lines Relating Basal Heat Production to Weight for Children of the Same Age and for Children of Different Ages

As nearly as possible a random selection of boys and girls differing in weight but approximately of the *same* age (within one year) was made from three groups of longitudinal data to determine whether the regression lines differed from those obtained for children of *different* ages. The results, shown in figure 27, indicate that the regression lines relating heat production to weight for children of *different* ages were ap-

TABLE 15.—*Number of children tested and number of measurements made for longitudinal-type data*
[From data on children within the Normal weight-for-height classification and School Age to Puberty age interval.]

	Colorado		California		New York		New York		Michigan		Texas	
	Lewis <i>et al.</i> (1937); Duval (1942) ¹		Eichorn (n.p.) ¹		Davenport <i>et al.</i> (1939) ¹		Webster <i>et al.</i> (1941) ¹		Hoobler (n.p.) ¹		Lamb (n.p.) ¹	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Children—	<i>Number</i>	<i>Number</i>	<i>Number</i>	<i>Number</i>	<i>Number</i>	<i>Number</i>	<i>Number</i>	<i>Number</i>	<i>Number</i>	<i>Number</i>	<i>Number</i>	<i>Number</i>
Tested.....	61	35	66	42	45	42	11	5	7	12	5	7
Having 1 or 2 measurements.....	8	6	25	29	11	21	3	1	0	5	1	4
Having more than 2 measurements.....	53	29	41	13	34	21	8	4	7	7	4	3
Measurements:												
Total.....	553	357	268	86	165	115	60	23	27	34	22	21
Average, for children having more than 2 measurements.....	10	12	6	4	4	4	7	6	4	4	5	6
Most for any 1 child.....	25	24	11	7	7	6	9	7	5	7	9	7

¹ For Literature References, see section XI.

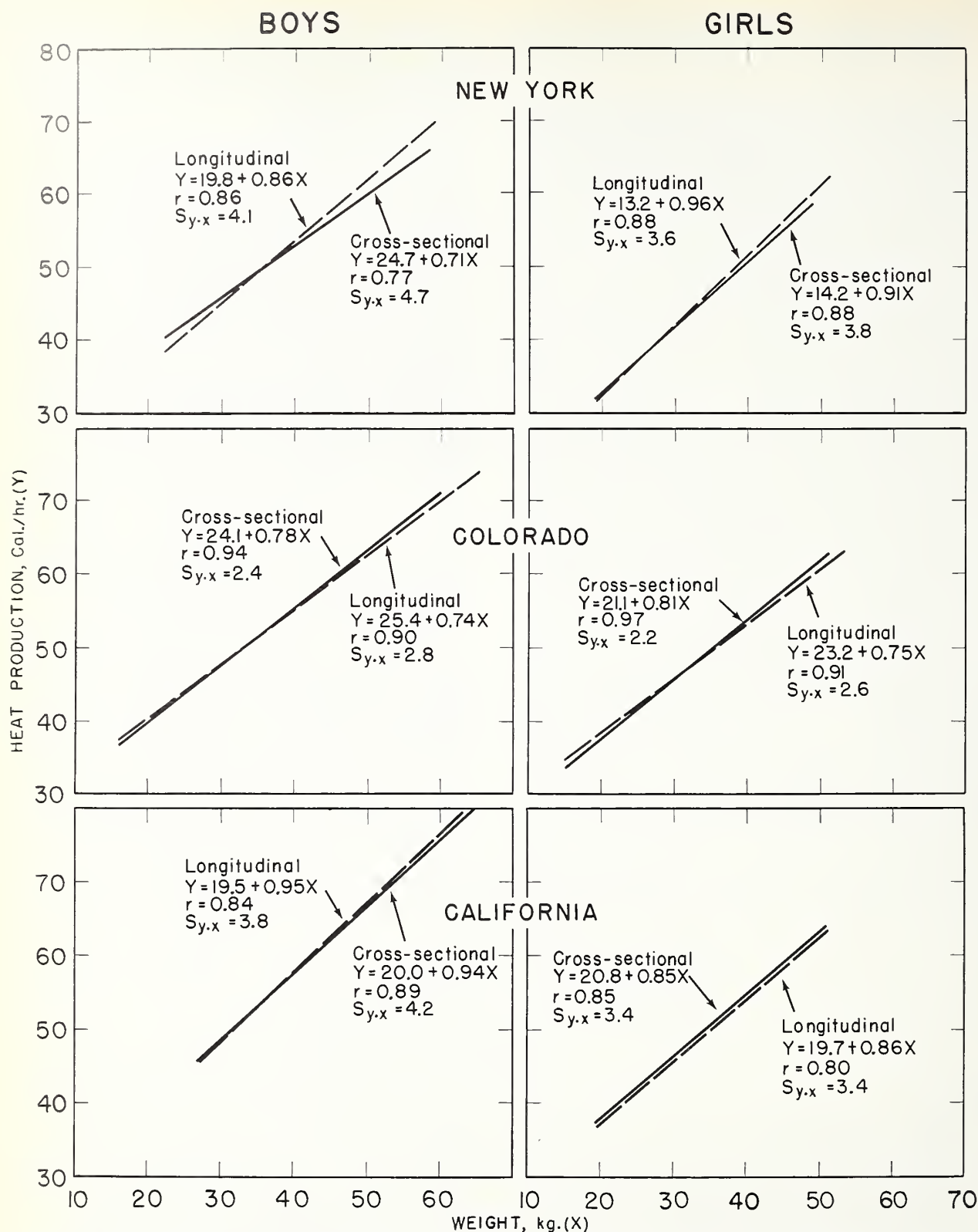


FIGURE 25.—CROSS-SECTIONAL AND LONGITUDINAL DATA: Regression lines relating basal heat production to weight.

See table 15 for number of measurements and number of children used. Data for New York, from Davenport, Renfro, and Hallock (1939); for Colorado, from Lewis, Kinsman, and Iliff (1937) and Duval (1942); for California, from Eichorn (n.p.).

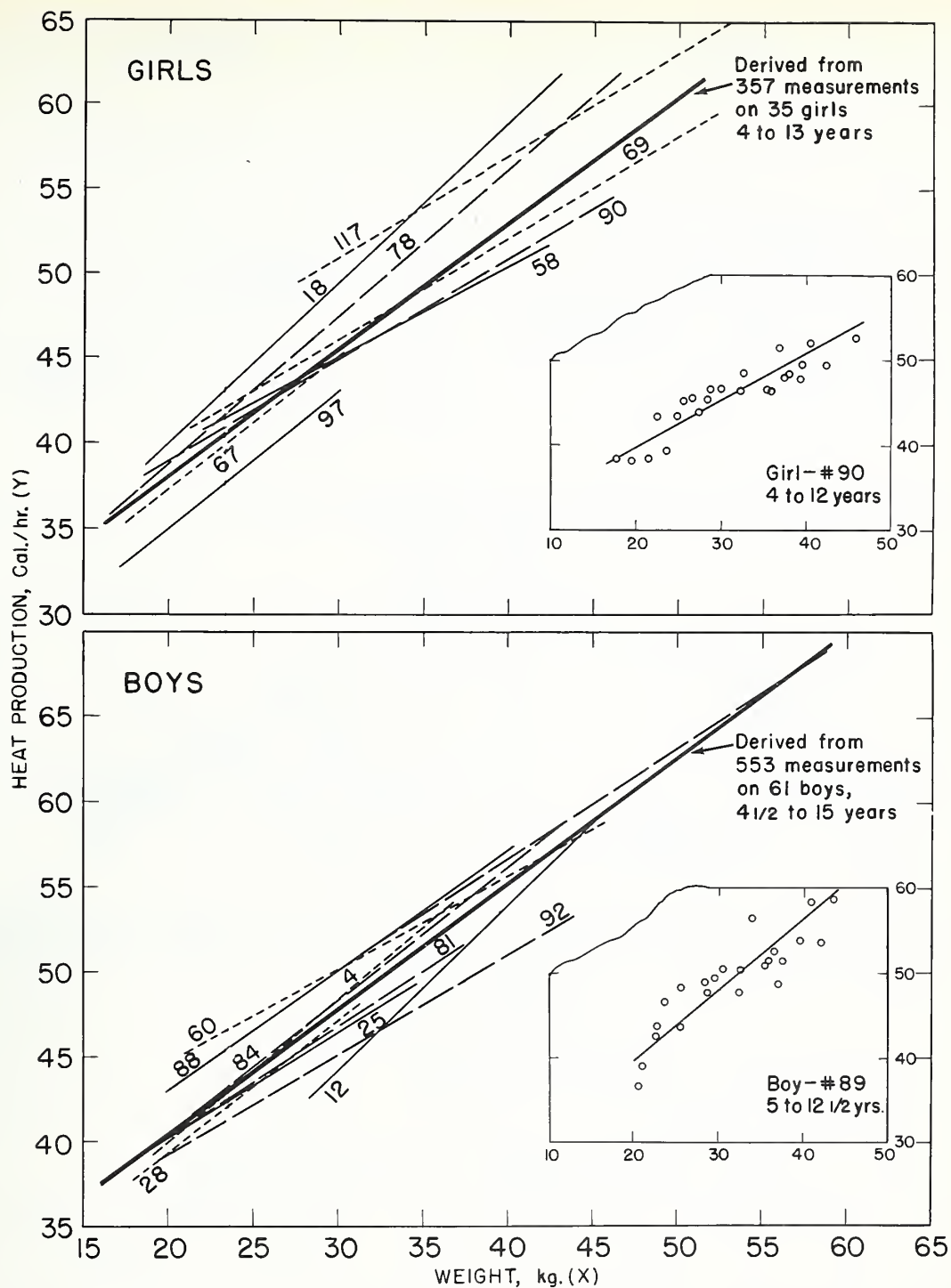


FIGURE 26.—MANY CHILDREN AND INDIVIDUAL CHILDREN MEASURED AT DIFFERENT AGES: Regression lines relating basal heat production to weight.

The inserts show the scatter of the data points about the regression line for an individual girl and boy. Data from Lewis, Kinsman, and Iliff (1937) and Duval (1942).

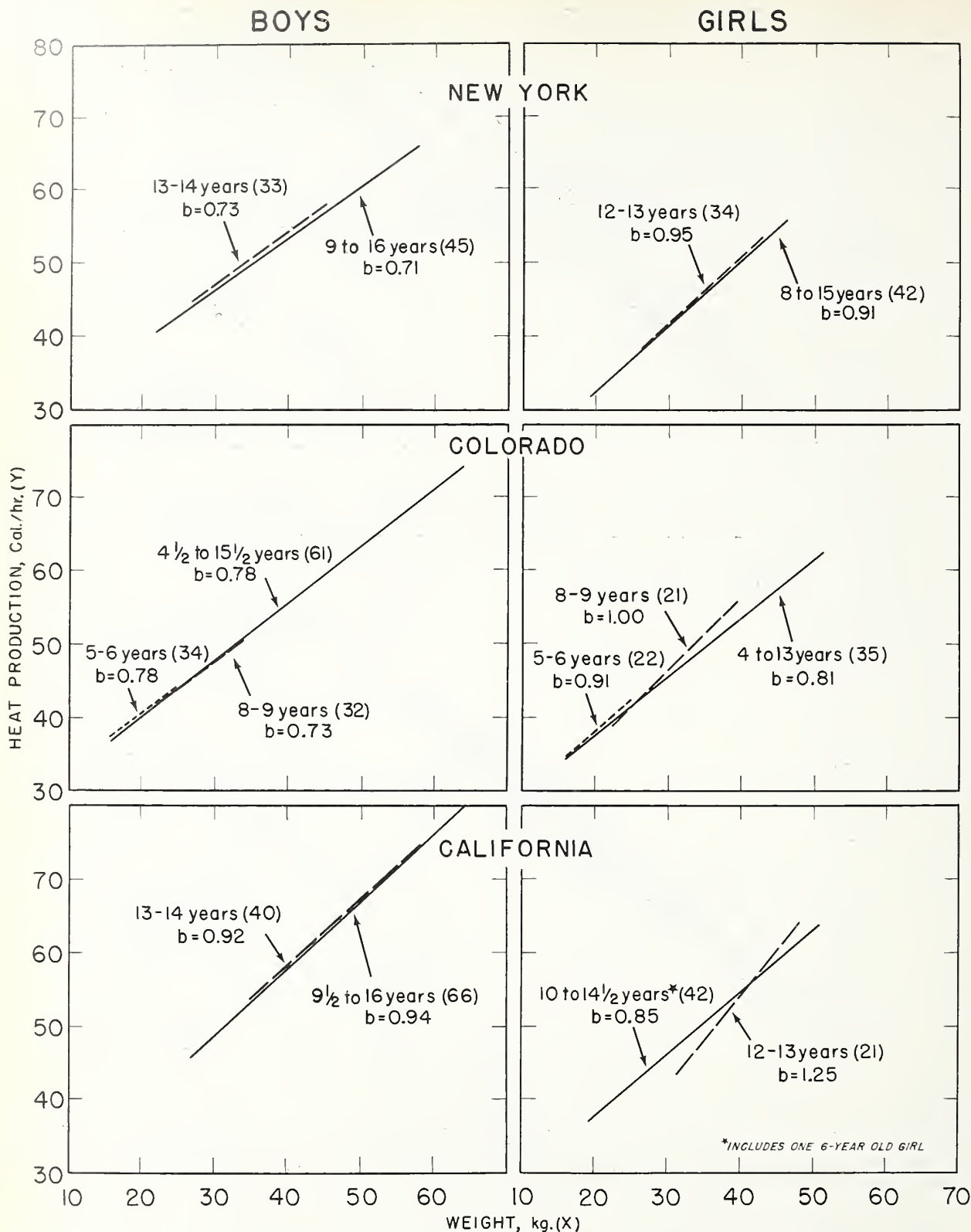


FIGURE 27.—CHILDREN THE SAME AGE BUT OF DIFFERENT WEIGHTS AND CHILDREN OF DIFFERENT AGES AND WEIGHTS: Regression lines relating basal heat production to weight.

The numerals in parentheses indicate the number of measurements used in deriving the equations. Data for New York, from Davenport, Renfro, and Hallock (1939) ; for Colorado, from Lewis, Kinsman, and Iliff (1937) and Duval (1942) ; for California, from Eichorn (n.p.).

plicable to children of different weights but of the same age.

Age as a Variable, in Addition to Weight, for Estimating Heat Production

Other than for indicating the average age at which physiological changes occurred, chronological age *per se* has been ignored in analyzing these data. To determine whether chronological age was a variable influencing heat production, the data on Colorado (Lewis *et al.*, 1937; Duval, 1942) and California (Eichorn, n.p.) children were divided into groups on the basis of their height for age. The children whose height for age fell in the 75th percentile or above by the Stuart-Meredith (1946) height-weight standards

were classified as "tall"; those with heights for age below the 25th percentile, as "short"; and those whose heights fell between the 25th and 75th percentiles, as "average" height for age. The separate regression equations for these groups are shown in figure 28.

If age were an influencing variable, the equation for the children of average height for age should fall between the other two groups. However, this occurred for only one group (California girls). In the other three groups the line representing children of average height for age was either above or below the other lines. It appears from these results that chronological age *per se* is not a factor affecting the level of heat production in children up to the age of puberty.

For more conclusive evidence that chronologi-

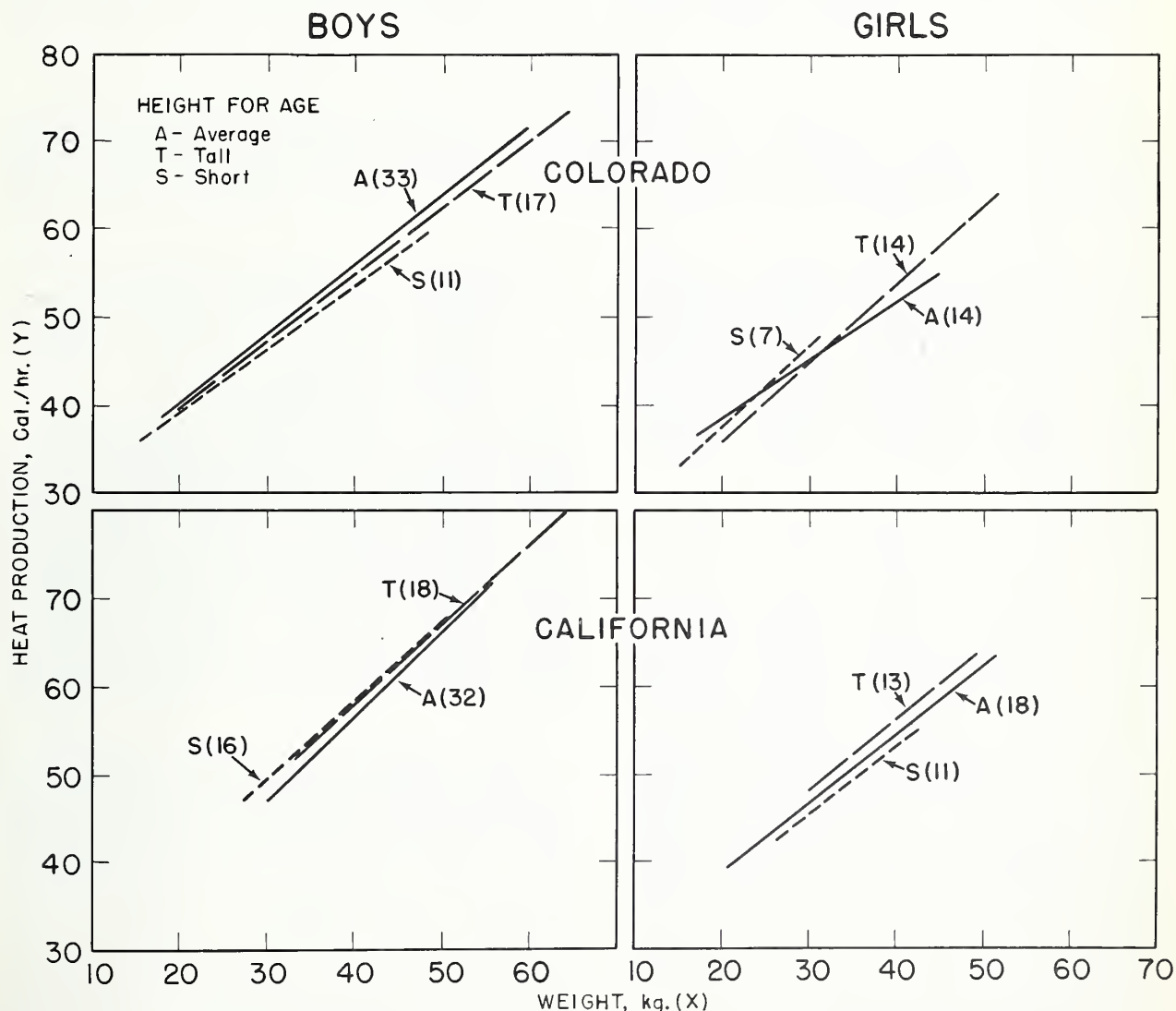


FIGURE 28.—CHILDREN "TALL FOR AGE," "AVERAGE" HEIGHT FOR AGE, AND "SHORT FOR AGE" WITHIN THE NORMAL WEIGHT-FOR-HEIGHT CLASSIFICATION: Regression lines relating basal heat production to weight.

The numerals in parentheses indicate the number of measurements used in deriving the equations. Data for Colorado, from Lewis, Kinsman, and Iliff (1937) and Duval (1942); for California, from Eichorn (n.p.).

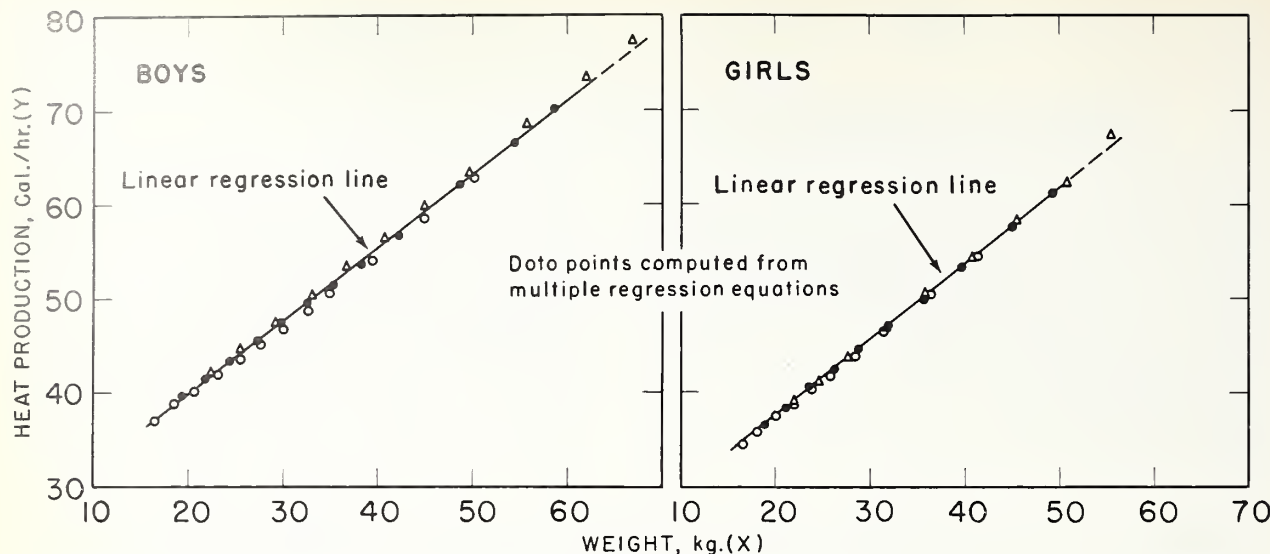


FIGURE 29.—Linear regression lines are compared with basal heat-production values computed from multiple regression equations.

Values for weight and age (5 to 14 years for girls and to 16 years for boys) corresponding to the 10th (closed circles), 50th (open circles), and 90th (triangles) percentiles from the Stuart-Meredith (1946) Standards were used as the basis for estimating heat production by multiple regression equations. See footnotes 2 and 3 in table 16 for the equations. Data from Lewis, Kinsman, and Iliff (1937) and Duval (1942) were used for the derivation of both equations.

cal age is relatively unimportant in estimating heat production of children, both weight and age were used as independent variables for deriving multiple regression equations. The same data on Colorado children (Lewis *et al.*, 1937; Duval, 1942) that were used for deriving linear equations for the cross-sectional type of data were used for computing multiple regression equations. The equations were:

Boys:

$$\text{Cal./hr.} = 24.5 + 0.87 (\text{weight, kg.}) - 0.35 (\text{age, yr.})$$

Girls:

$$\text{Cal./hr.} = 21.3 + 0.84 (\text{weight, kg.}) - 0.13 (\text{age, yr.}).$$

Thus, heat production for boys increased an average of 0.87 Calories per hour for each kilogram increase in body weight but only 0.35 Calories per hour for each yearly increase in age. The effect of age on heat production for girls was less than for boys. Because the partial regression coefficient of age (independent of weight) was negative, young children of a given weight who are taller than others of their age had a slightly higher metabolism.

The following statistical test (see Snedecor, 1956, p. 419) gives further evidence that chronological age is of minor importance in estimating heat production of children. Test of each variable after the effect of other variable was removed:

Boys:

Mean square for age after weight dis-	
counted -----	11.37
Mean square for weight after age dis-	
counted -----	843.99**
Mean square for error -----	8.48

Girls:

Mean square for age after weight dis-	
counted -----	0.61
Mean square for weight after age dis-	
counted -----	388.08**
Mean square for error -----	5.20

**=Significant at the 1-percent level.

Table 16, in which actual measurements on children were used for illustration, indicates that heat production was approximately the same whether computed by the linear regression or by the multiple regression equation. Theoretically, the maximum difference possible between heat-production values computed by the linear equation (weight as single variable) and by the multiple regression equation (weight and age as variables) for children of the same weight but differing in age would be less than 2 Calories per hour for boys and less than 1 Calorie per hour, for girls.

Linear regression lines are shown in figure 29, in which heat-production values computed by multiple regression equations for weights and ages of boys and girls corresponding to the 10th, 50th, and 90th percentiles of the Stuart-Meredith (1946) Standards are shown in relation to the linear regression equation. Inasmuch as the standard error of estimate was higher than the maximum possible difference between the two types of equations, it was considered unnecessary to calculate the multiple regression equation for other data, especially, since this equation was not superior to the linear equation, and the simpler method was preferred for processing the data.

Summarizing the results pertaining to methods

of analyzing the data, it was found that the regression equations were similar whether they were derived from cross-sectional or longitudinal types of data; that the regression lines for individual children measured at different ages and those for children of approximately the same age (within one year) but of different weights were similar to the regression lines derived from data on many children of different ages. Little difference was found among the equations derived for groups of children tall, short, or of average height for their age, and the results were not consistent for all groups. Therefore, it is concluded that chronological age *per se* is relatively unimportant as a variable influencing basal heat production within

a given physiological age interval.

That weight is the chief variable influencing heat production and that chronological age is relatively unimportant was indicated also from multiple regression equations. In estimating heat production of children, the maximum difference possible between the multiple regression equation (both age and weight as variables) and the linear regression equation (weight as the single variable) would be less than 2 Calories per hour (for the data used in this analysis). This difference is less than the standard error of estimate. Thus, the simpler linear equation (as computed in section VII) is preferable for estimating basal heat production.

TABLE 16.—Heat production computed by linear regression and by multiple regression equations for children of different heights for age

Colorado Subject No. ¹	Age	Weight	Height	Heat production			Deviation from actual	
				Actual	Calculated		Linear	Multiple
					Linear ²	Multiple ³		
Boys:	Yr. Mo.	Kg.	Cm.	Cal./hr.	Cal./hr.	Cal./hr.	Cal./hr.	Cal./hr.
23	5 1	18.6	107.8	36.3	38.6	38.9	+2.3	+2.6
16	5 2	20.0	111.7	37.8	39.7	40.1	+1.9	+2.3
116	5 1	23.4	123.8	45.9	42.3	43.1	-3.6	-2.8
60	8 1	22.7	119.4	44.7	41.8	41.4	-2.9	-3.3
27	8 3	27.7	130.9	45.2	45.7	45.8	+0.5	+0.6
5	8 3	31.4	137.6	45.3	48.5	49.0	+3.2	+3.7
110	11 2	29.8	140.0	49.0	47.3	46.6	-1.7	-2.4
93	11 4	34.0	146.3	45.3	50.6	50.0	+5.3	+4.7
92	11 5	40.6	154.2	53.1	55.7	55.8	+2.6	+2.7
12	14 4	40.0	153.1	51.6	55.2	54.2	+3.6	+2.6
61	14 7	46.5	162.4	65.3	60.3	59.9	-5.0	-5.4
48	14 4	50.1	169.2	61.1	63.1	63.0	+2.0	+1.9
Girls:								
68	5 0	16.6	107.3	36.2	34.6	34.7	-1.6	-1.5
97	4 10	17.7	110.3	35.0	35.5	35.6	+0.5	+0.6
18	5 2	20.2	118.1	40.8	37.6	37.7	-3.2	-3.1
21	7 9	21.8	121.0	38.4	38.9	38.7	+0.5	+0.3
67	8 1	27.9	125.6	42.2	43.8	43.8	+1.6	+1.6
117	8 0	29.9	137.8	49.6	45.5	45.5	-4.1	-4.1
72	10 10	34.9	140.7	45.4	49.5	49.4	+4.1	+4.0
78	11 3	36.3	150.4	52.3	50.7	50.6	-1.6	-1.7
117	11 3	45.5	157.6	60.8	58.2	58.3	-2.6	-2.5
73	12 11	33.8	146.4	45.3	48.6	48.2	+3.3	+2.9
69	12 10	51.8	161.8	62.0	63.3	63.4	+1.3	+1.4

¹ Subjects within the Normal weight-for-height classification were selected on the basis of height for age from the longitudinal data of Lewis, Kinsman, and Iliff (1937) and Duval (1942); these subjects for this age were not included in the derivation of the linear equation from the cross-sectional data.

² Equations for linear regression: Boys, Cal./hr. = $24.11 + 0.778$ (weight, kg.); girls, Cal./hr. = $21.09 + 0.815$ (weight, kg.).

³ Equations for multiple regression: Boys, Cal./hr. = $24.47 + 0.870$ (weight, kg.) - 0.348 (age, yr.); girls, Cal./hr. = $21.28 + 0.845$ (weight, kg.) - 0.127 (age, yr.).

IX.—An Attempt at Integration

The regression lines derived from data for boys and girls within the School Age to Puberty age interval are shown by regions in figure 30 for the Normal weight-for-height classification and in figure 31 for the Overweight. These figures show that in some regions the regression lines for a given age interval or weight-for-height classification are similar, in some the lines are nearly parallel but differ in elevation, and in some the lines are mostly dissimilar. Little meaning can be attached to differences in elevation unless the slopes are parallel, and since it was concluded from the preceding section that the slopes of the regression lines were unaffected by the subject's experience with the metabolic procedure or by the method used in calculating the final results, a thorough examination of the *slopes* was made.

It appears that the slopes of the regression lines may be the same for boys and girls within the School Age to Puberty age interval, since the slopes derived for boys were similar to the corresponding slopes derived for girls for three locations, and for the other locations they were sometimes lower and sometimes higher. However, statistical tests (covariance analysis) were made for verification. These results (*see* appendix B, table 25) indicated that the slopes of the regression lines were similar for boys and for girls within the Preschool and, with three exceptions, within the School Age to Puberty age intervals for both the Normal and Overweight weight-for-height classifications. These exceptions were as follows:

The slopes of the regression lines derived from the data of Topper and Mulier (1929a, 1929b, 1932) for girls within both the Normal and Overweight weight-for-height classification are considerably higher than the corresponding slopes from the other locations (*see* right set of equations in tables 7 and 10). However, the difference in slopes between the boys and girls was significantly higher only for the Normal weight-for-height classification. Because the slopes of all other pairs of boys and girls within the Normal weight-for-height classification were not significantly different, the relatively steep slope (1.39) of the regression line for the Normal girls (of Topper and Mulier) was apparently due to sampling variation.

The slope (0.86) of the regression line for Overweight boys derived from Taylor's (n.p.) data was the steepest one obtained from data for Overweight boys and was steeper than the corresponding slope (0.75) for Normal boys, which was one of the flatter slopes obtained (*see* right set of equations in

tables 6 and 9). Hence, this relatively steep slope apparently caused the difference between the slopes of Overweight boys and girls (from Taylor, n.p.) to be significant.

The significant difference between slopes for the Overweight boys and girls from Colorado (Lewis *et al.*, 1937; Duval, 1942) was believed to be caused by the relatively flat slope (0.56) of the regression line for Overweight girls. As explained in section VII this slope was attributed to a few aberrant values in the small group represented (*see* right set of equations in tables 9 and 10). The slope for Overweight girls was significantly lower than that (0.78) for Normal girls, whereas the slopes for Overweight and for Normal boys were the same (0.74).

It is concluded that the *slopes* of the regression lines for boys and girls within the Preschool and School Age to Puberty age intervals are not significantly different: therefore, the data for both sexes within a given location were combined. The slopes derived from the combined data are given in table 17. These slopes for a given region were more uniform than those calculated separately for boys and for girls and probably are more representative of the given location because of the larger number of measurements available. The results of covariance analysis (given in appendix B, table 26) indicate that:

1. For the Preschool age interval the slopes of the regression lines are not significantly different. Since this age interval was represented by only three locations, these results cannot be considered conclusive.
2. For the School Age to Puberty age interval the slopes of the regression lines are not in agreement for all locations within any geographical region for the Normal weight-for-height classification. However, the slopes of the regression lines among all locations were not significantly different for Overweight children.

Table 17 shows that for the Normal weight-for-height classification there was one location having a slope out-of-line with all others; that is, the slope of 0.76 (data from Taylor, n.p.) appeared to be out-of-line with others in the Northeast region; the slope of 0.63 (data from Wang *et al.*, 1926, 1936; and Wang, 1934, 1939) was out-of-line in the North Central Region; and the slope 0.97 (data from Eichorn, n.p.) was steeper than others in the Western Region. These

BOYS

GIRLS

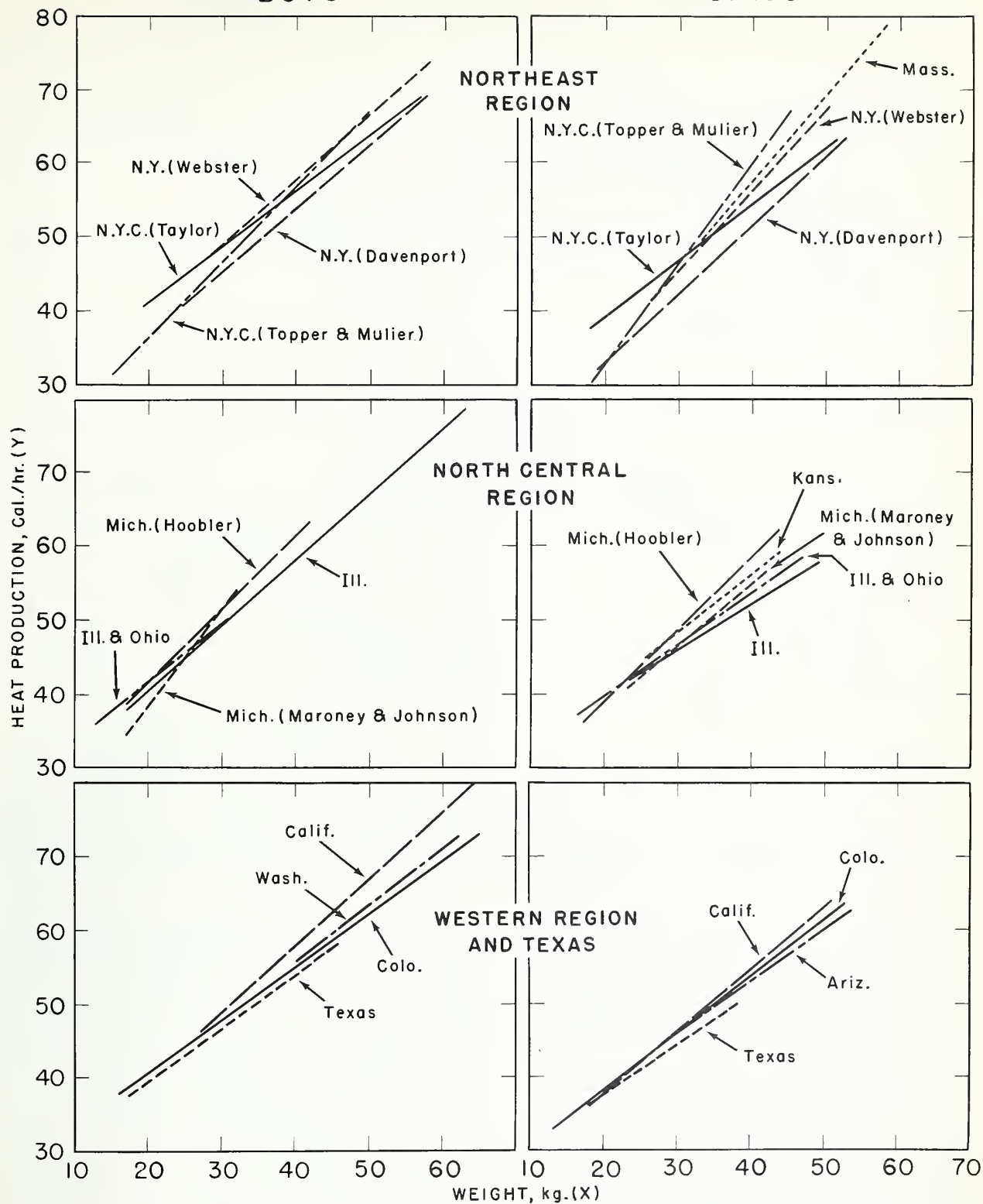


FIGURE 30.—BOYS AND GIRLS WITHIN THE NORMAL WEIGHT-FOR-HEIGHT CLASSIFICATION AND SCHOOL AGE TO PUBERTY AGE INTERVAL: Regression lines relating basal heat production to weight.

See tables 6 and 7 for sources of data and equations.

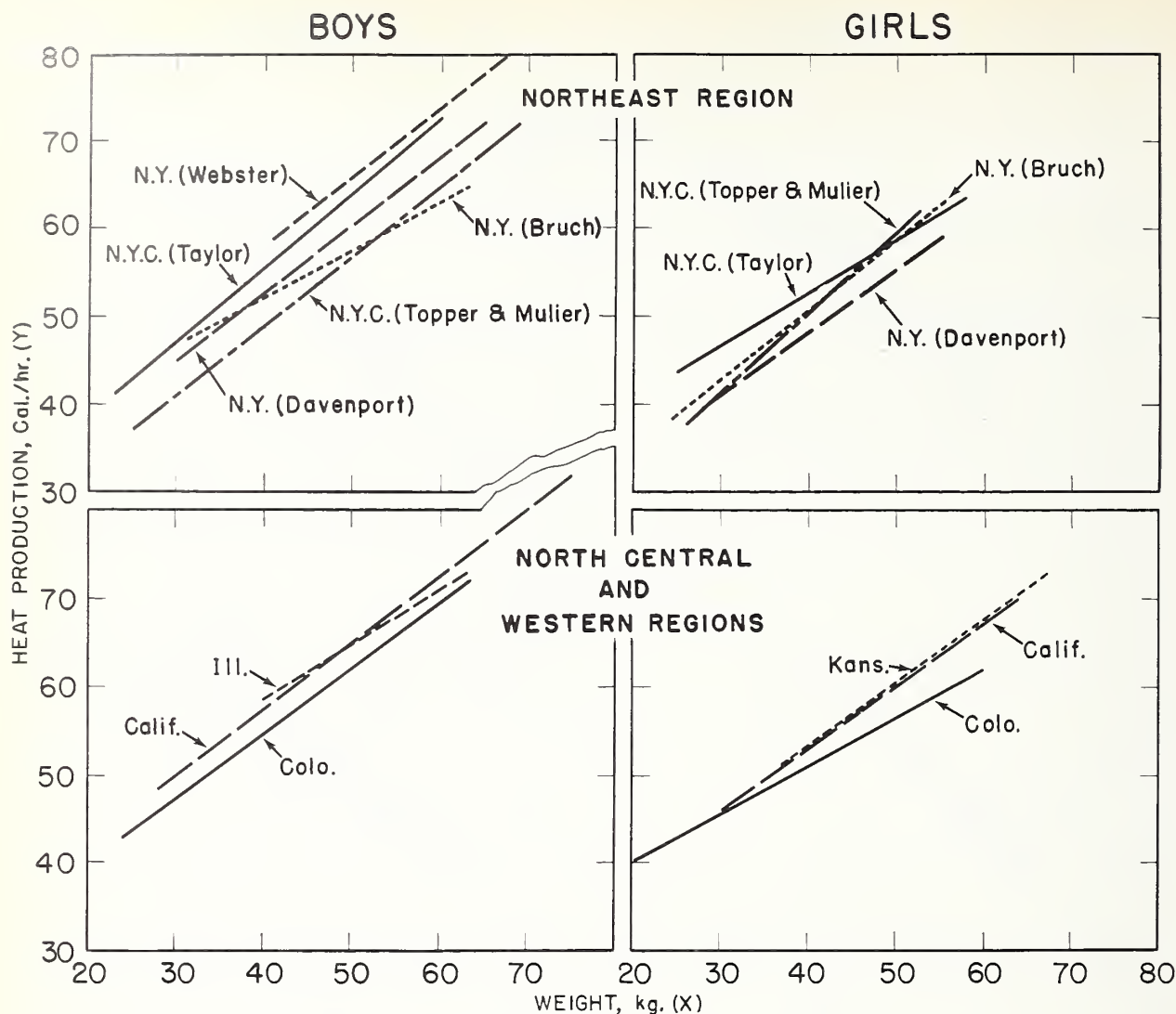


FIGURE 31.—OVERWEIGHT BOYS AND GIRLS WITHIN THE SCHOOL AGE TO PUBERTY AGE INTERVAL: Regression lines relating basal heat production to weight.

See tables 9 and 10 for sources of data and equations.

slopes are from groups having a relatively large number of measurements and cannot be explained. With these exceptions, the slopes in the Northeast region were near 1.0; in the North Central region they were slightly lower—nearer 0.9; whereas in the Western region and Texas they were close to 0.8.

The difference in the weight range and in the distribution (scatter) of the data along the regression lines may be factors contributing to differences in the slope of the regression lines within a region. The weight range varied considerably among the locations (see tables 6 and 7); this was determined to a large extent by the age range of the children measured (see table 3). For example, most of the Texas boys were between 18 and 25 kilograms, most of the Colorado

boys between 18 and 40 kilograms (although the range extended to 65 kilograms), most of the California boys between 30 and 60 kilograms, and most of the Washington boys between 48 and 60 kilograms. In addition, the distribution (scatter) of the data along the regression line was often skewed. This may have caused the regression lines to be somewhat distorted.

The regression lines derived from data for boys within the Postpubertal age interval are shown for both Normal and Overweight weight-for-height classifications in figure 32 and the corresponding regression lines for Postpubertal girls in figure 33. There were fewer data for the Postpubertal age interval than for the School Age to Puberty age interval, so that results of the analysis are less conclusive. However, for the avail-

TABLE 17.—*Regression coefficients for children within the Preschool and School Age to Puberty age intervals (data for boys and girls combined)*

Location	Investigator(s) ¹	Weight-for-height classification	
		Normal	Overweight
	Preschool		
New York City	Taylor (n.p.)	1. 90	
Texas	Lamb (n.p.)	1. 86	
Colorado	Lewis <i>et al.</i> (1937); Duval (1942)	1. 40	
	School Age to Puberty		
Northeast Region:			
Massachusetts	Talbot <i>et al.</i> (1937)	² 1. 29	
New York City	Taylor (n.p.)	. 76	0. 72
Do	Topper and Mulier (1929a, 1929b; 1932)	1. 19	. 83
New York	Davenport <i>et al.</i> (1939)	. 94	. 81
Do	Webster <i>et al.</i> (1941)	1. 00	³ . 79
New York City	Bruch (1939a, 1939b, 1942)		. 68
North Central Region:			
Illinois and Ohio	Wang (1934, 1939); Wang <i>et al.</i> (1926, 1936)	. 63	
Illinois	Morse (n.p.)	. 91	³ . 62
Michigan	Maroney and Johnston (1937)	. 93	
Do	Hoobler (n.p.)	. 93	
Kansas	Harrison (n.p.)	² . 82	² . 70
Southern Region: Texas	Lamb (n.p.)	. 76	
Western Region:			
Colorado	Lewis <i>et al.</i> (1937); Duval (1942)	. 77	. 70
Arizona	Thompson (n.p.)	² . 73	
Washington	Esselbaugh (n.p.)	³ . 79	
California	Eichorn (n.p.)	. 97	. 74

¹ For Literature References, *see* section XI.² Data for girls only.³ Data for boys only.

able data within the Postpubertal age interval, the slopes of the regression lines for boys within the Normal weight-for-height classifications were significantly steeper than the corresponding slope for girls in three (of four) locations (*see* appendix B, table 25). Hence, the data could not be combined, although the differences between the slopes of Overweight boys and girls were not significantly different for any of the three locations having data for both sexes.

Covariance analysis on Postpubertal boys and girls (*see* appendix B, table 27) indicated that there was a significant difference in the slopes for all locations. However, when the locations were divided into two regions—Northeast-North Central combined and Western—the slopes were not significantly different. The slopes, on the average, appeared to be less steep for the girls in the Western region, but because of the greater variability of the Postpubertal age interval, it was difficult to make any conclusive statements. The locations representing the boys were too limited for summarizing by regions.

On the basis of climatic conditions, the locations representing the Northeast and North Central regions were similar (although, the mean annual temperature is slightly higher in Kansas) and were more nearly comparable than were locations within the Western region. Meteorological records indicate that Colorado (Denver) has a lower annual temperature and a lower relative humidity than the other locations in the Western region and, although Arizona (Tucson) has a low relative humidity, the annual temperature is much higher. California (San Francisco) has a somewhat lower annual temperature but a considerably higher relative humidity than Arizona (Tucson) and, whereas the relative humidity of Washington is more nearly comparable to that of California, the annual temperature is considerably lower. Hence, even though locations may be in the same geographical region, the annual temperature and relative humidity may differ, so that it appears doubtful that differences among the regions represented herein can be explained by climatic conditions. Altitude was not con-

BOYS

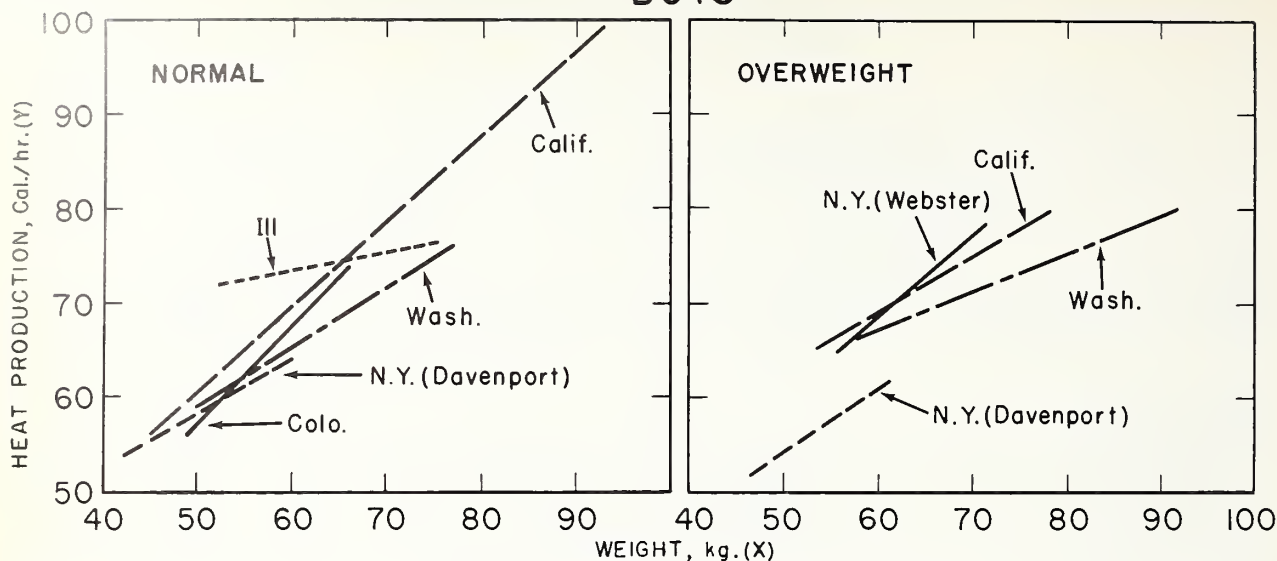


FIGURE 32.—POSTPUBERTAL BOYS WITHIN THE NORMAL AND OVERWEIGHT WEIGHT-FOR-HEIGHT CLASSIFICATIONS: Regression lines relating basal heat production to weight.

See tables 6 and 9 for sources of data and equations.

sidered a factor, since the report by Lewis *et al.* (1943b) appeared to give conclusive evidence that heat production is not affected by altitude.

Because the slopes within any region were not in agreement for the School Age to Puberty age interval (which was represented by the most locations and most measurements), and because no explanation can be offered for the slopes which appeared to be "out-of-line," we were not justified in attempting to integrate these data further. It would be futile to make any estimates for a in the equation ($Y=a+bX$) relating heat production to weight so as to determine the elevation of the regression lines. This value would be different for boys and girls and, as shown in the preceding section, would be slightly different for the various methods of computing the "final" heat production values.

The differences in elevation of the regression lines for boys and for girls (within the School Age to Puberty age interval and Normal weight-for-height classification), however, may be estimated for locations in which the slopes were approximately equal and also by computation of the heat production for a specific weight from the derived equations. For the locations (Taylor, n.p.; Hoobler, n.p.; and Lewis *et al.*, 1937, and Duval, 1942) in which the slopes of regression lines for boys and girls were approximately the same, the differences in the Y -intercept (value of a in the equation) were 2.6, 2.6, and 3.2 Calories per hour. Values of approximately the same magnitude were obtained from the difference in heat production computed from the equations for boys and girls, using a weight of 35 kilograms

(see last two columns of table 15). Thus, the regression line relating heat production to weight was about 3 Calories per hour higher for the boys within the School Age to Puberty age interval and Normal weight-for-height classification.

The equations⁴ derived from the published data of Bierring (1931) and Vogelius (1945) for Danish boys and girls within the School Age to Puberty age interval and Normal weight-for-height classification have substantiated our conclusions that the slopes of the regression lines for boys and girls were similar and that the elevation of the regression line was approximately 3 Calories per hour higher for the boys.

The difference in the elevation of the regression lines for Overweight boys and girls (within the School Age to Puberty age interval) was about 5 Calories per hour higher for the boys. However, since fewer locations were represented for Overweight than for Normal children and because there was a greater discrepancy between the slopes, little confidence can be given to this estimate. Although the slopes of the combined data (boys and girls) on Overweight children appeared to be less steep than those of the Normal children (see table 17), statistical tests indicated that the difference was not significant except for the data from Topper and Mulier (1929a, 1929b, 1932) and from Eichorn (n.p.). These results are in accordance with those presented in section VII (see table 11), when similar

⁴ Boys: Heat production, Cal./hr.=22.3+0.88(weight, kg.)

Girls: Heat production, Cal./hr.=19.1+0.88(weight, kg.)

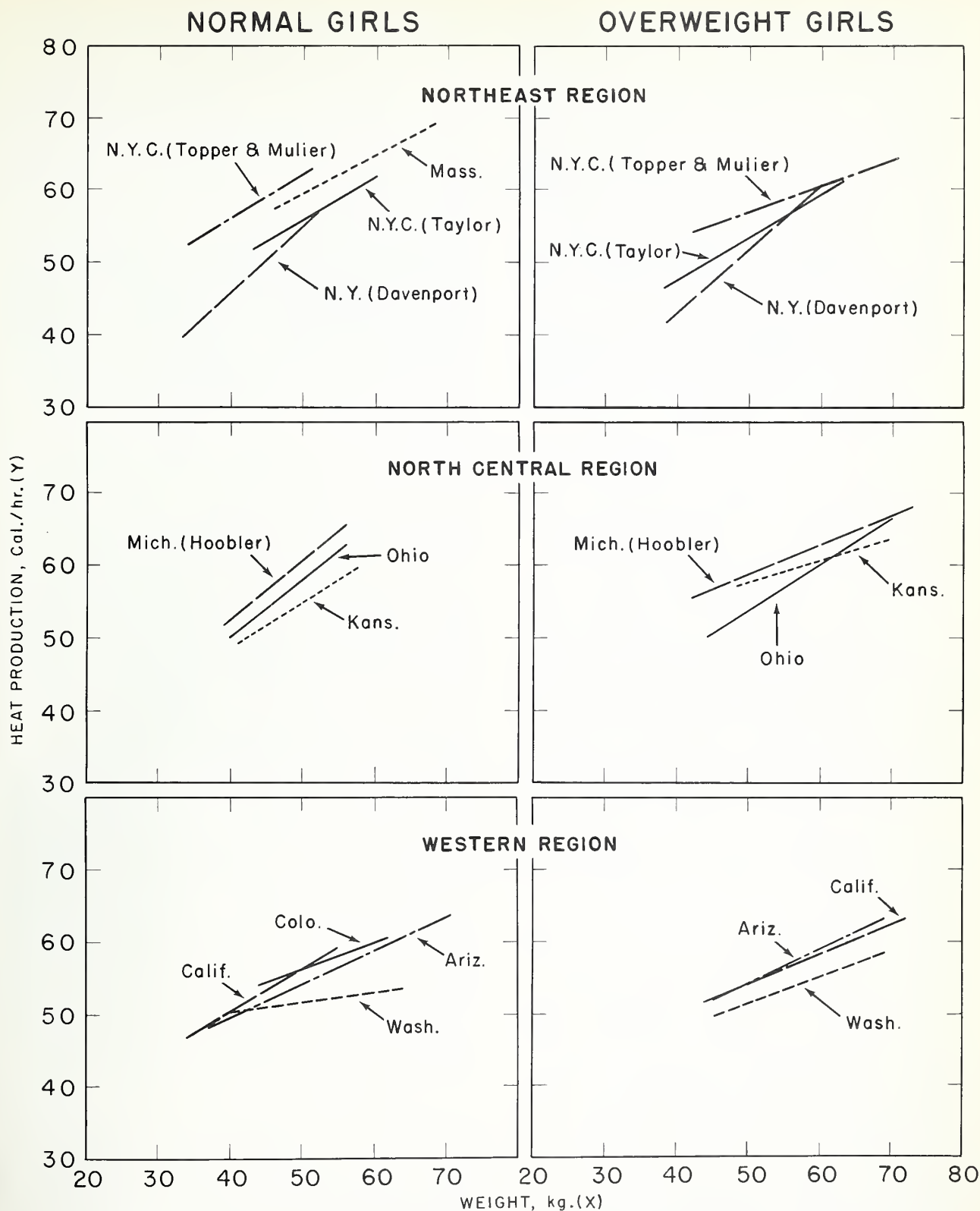


FIGURE 33.—POSTPUBERTAL GIRLS WITHIN THE NORMAL AND OVERWEIGHT WEIGHT-FOR-HEIGHT CLASSIFICATIONS: Regression lines relating basal heat production to weight.

See tables 7 and 10 for sources of data and equations.

comparisons were made separately for each sex.

Theoretically, we should be able to estimate the difference in elevation of the regression lines for Normal and Overweight children. Such an estimation is complicated because of differences in the weight range covered by the two groups and because differences in slope, although statistically insignificant, cause discrepancies. Thus, a comparison of the regression lines of Normal and Overweight children varies according to the weight used. For example, heat-production values computed for a weight of 40 kilograms for Normal and Overweight children varied from zero to about 10 Calories for the locations represented.

The slopes of the regression lines appeared to be significantly different for boys and girls in the Postpubertal age interval. But because the data for boys for this age group were limited,

comparisons between boys or girls or between weight-for-height classifications for this age interval could not be made.

It is obvious that before further integration of the available data on heat production can be made, additional data, obtained under conditions that are more standardized than are available at present, are needed. It is desirable that the age and weight range of boys and girls measured be more comparable among the locations and that a greater number of locations be represented for each geographical region. The effect of climatic conditions on heat production can then be analyzed. Until such data are available to serve as a basis for estimating heat production of children more accurately, heat production may be estimated from weight by using any of the equations derived herein—the choice to be made according to similarity of region and procedure.

X.—Summary

Basal metabolic data from 18 investigators consisting of 2,656 measurements on boys from 2 to 18 years old and 2,832 measurements on girls from 2 to 16 years old were analyzed. For comparative purposes, additional data consisting of 68 measurements on boys from 18 to 27 years old and 454 measurements on girls from 16 to 24 years old also were analyzed.

A preliminary analysis of the data according to height-weight-age division demonstrated that the traditional method of relating heat production per unit of body surface to age did not correct for differences in the physical size of the children. The average basal metabolism of children "large for age" was lower than for "average" children, whereas the metabolism of children "small for age" was higher.

Chronological age is not a satisfactory reference base because of the great variation in size of children for a given age. Therefore, a system of classifying children according to their weight for height (disregarding chronological age) was developed.

This classification was developed by plotting on semilogarithmic paper the 50th percentile values from the Stuart-Meredith height-weight standards. The straight line drawn through these values was used to represent the average relationship between weight and height of children 2 years of age to puberty. From this average line it was estimated that weight (in kilograms) increased at a constant rate of 1.8 percent for each centimeter increase in height, and was approximately the same for boys and girls.

Lines at designated intervals above and below the average line were used to separate the data for children into the following six weight-for-height classifications: Normal (within plus and minus 10% of the average line), Stocky (within +10 and +20%), Overweight (within +20 and +40%), Obese (40% or more), Slender (within -10 and -20%), and Underweight (-20% or more).

Although there was a pronounced upward trend after puberty in the relationship between weight and height for average groups of girls, and sometimes for boys, this trend is undesirable and is believed to be a distortion caused, in part, by the tendency for the percentage of fat to increase as maturity is approached.

From the age curves (plotted from longitudinal

data) it was concluded that basal heat production increases during the prepubertal growth spurt but parallels the increase in physical size so that when correlated with weight, no change in the rate is evident. However, changes in the basal metabolic rate were evident, which corresponded to certain physiological changes, and occurred at the following times:

1. At 4 or 5 years of age, at which time there is a corresponding change in the rate of growth in height;
2. At puberty, which also corresponds to a change in the growth rate of height; and
3. Following puberty, at which time the basal metabolic rate varies considerably for several years until physiological maturity is reached, after which it appears to become more stabilized.

These changes in the basal metabolic rate were the basis for separating the data into the following physiological age intervals: Preschool, School Age to Puberty, and Postpubertal.

For each physiological age interval and weight-for-height classification, linear equations relating basal heat production (Calories per hour) to weight were derived separately for the available data from each location (or investigator). From these linear equations it was concluded that:

1. The increase in basal heat production (Cal./hr.) per unit of increase in weight is greatest for the Preschool and least for the Postpubertal age interval; the elevation of the regression line for the Postpubertal interval lies between the regression line for the School Age to Puberty age interval and the regression line for the older age interval.
2. The equations relating basal heat production (Cal./hr.) to weight are the same for children in Normal and Slender weight-for-height classifications and the same for children in Stocky and Overweight classifications. Data for Underweight and Obese children were inadequate for analysis.
3. The regression lines relating basal heat production to weight for Overweight children are parallel to regression lines for children in the Normal weight-for-height classification but are at lower elevations.

4. The *slopes* of the regression lines for boys and girls within the Preschool and School Age to Puberty age intervals are the same, but the *elevation* of the regression lines is lower for the girls. For the Normal weight-for-height classification and School Age to Puberty age interval the elevation of the regression line relating basal heat production to weight is approximately 3 Calories per hour higher for the boys than for the girls.

Additional analyses indicated that regression equations were comparable whether derived from cross-sectional or longitudinal data; whether derived from data for individual children measured at different chronological ages, for many children of different ages, or for many children of approximately the same age but of different weights. The regression lines derived by the various methods currently used for selecting values to report basal metabolic measurements were parallel (had same slopes) but were at different elevations. The elevation of the regression lines derived from using the mean of all tests were significantly higher than the regression lines derived from using the lowest test.

Integration was impossible, owing to significant differences among the slopes of the regression lines within each geographical region. We have no explanation for these differences but are of the opinion that differences in weight range, along with a skewed distribution (or scatter) of some of the data included in the various studies analyzed, caused a distortion in the regression

lines. In spite of the disagreement within regions, the slopes of most of the regression lines were steepest for data from the Northeast region and flattest for the Western region.

Additional data from more locations are needed before equations can be derived for estimating heat production of children in different weight-for-height classifications within physiological age intervals which will be applicable to a given region or climate within the United States. Basal metabolic measurements are equally satisfactory whether obtained by the open- or closed-circuit apparatus, but it is important that experience or training of the children and method of selecting a value for reporting basal metabolic results be standardized.

On the basis of results obtained from analyzing individual test data, it is recommended that preliminary testing (which need not be made under post-absorptive conditions) be made on inexperienced children in order to familiarize them with the apparatus and to promote relaxation. Because of individual differences in adaptation to the procedure there can be no set rule as to how many tests should be obtained. However, tests on at least two mornings should be made in order to be certain that the result is reliable and that apprehension, or some other disturbance, has not affected the results. If the test on the second test morning is substantially lower than that on the first test, it would be desirable to repeat the test for a third morning. With exception of extreme values, which should be omitted, the final value to be reported should be the mean of all tests.

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⁵ For unpublished data, "n.p." (not published) appears in place of the date of publication.

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XII.—Appendix A.—Supplemental Analysis of Data

As mentioned in section IV, the Stuart-Meredith (1946) height-weight standards for children 5 to 18 years of age were used (no attempt was made for separating data for children below 5 or above 18 years) as a basis for separating the data for children into height-weight-age divisions. According to the percentile with which the height and weight for a given age of the child corresponded, the following five height-weight-age divisions were established (insufficient data were available for a further break-down for the "overweight" and "underweight" children into tall, average, or short in height for age).

Division	Percentile for height	Percentile for weight
Average-----	25th up to 50th--	10th up to 75th.
	50th up to 75th--	25th up to 90th.
Large-----	75th up to 90th--	50th and above.
	90th and above--	75th and above.
Small-----	Below the 10th--	Below the 25th.
	10th up to 25th--	Below the 50th.
Overweight-----	Below the 10th--	25th and above.
	10th up to 25th--	50th and above.
	25th up to 50th--	75th and above.
	50th up to 75th--	90th and above.
Underweight-----	25th up to 50th--	Below the 10th.
	50th up to 75th--	Below the 25th.
	75th up to 90th--	Below the 50th.
	90th and above--	Below the 75th.

SURFACE AREA IN RELATION TO AGE

These height-weight-age divisions provided a means of testing the assumption that body surface corrects for differences due to body size. Average values for height, weight, and basal heat production for each of the five divisions in which there were at least 10 measurements within any 6-month age interval are given in tables 18 and 19. These tables, and also figure 34, indicate that for a given location heat production per unit of body surface related to age was not the same for all height-weight-age divisions; that is, body surface as a reference base did not compensate for differences in body size. The large children had a lower and the small children a higher heat production per unit of body surface than children of average height and weight of the same age (figure 34, left sections). Overweight boys had a higher and underweight boys a lower heat production per unit of body surface than average boys of the same age (figure 34, lower right section). No consistent difference between the data for overweight and underweight girls was evi-

dent. (Since the overweight and underweight groups were composed of children that were either tall, average, or short for their age, there were greater variations and discrepancies between age intervals.)

Although it is shown in figure 34 that there was little, if any, difference in heat production (Cal./sq.m./hr.) for the three curves between ages 12 and 14 years in the boys and 11 and 13 years in the girls, this was due to an increase in heat production for the large children in contrast with the other two curves which continued to decline for the girls or remained almost constant for the boys. This increase in heat production of large children during this age interval was probably related to their early acceleration in physical growth during this period.

Figure 35 shows that heat production (Cal./sq.m./hr.) was not the same for children within a given height-weight-age division (average, large, or small) measured by different investigators. Thus, the average heat production (Cal./sq.m./hr.) for a given age was lower for New York (Davenport *et al.*, 1939) and Colorado (Lewis *et al.*, 1937; Duval, 1942) boys than for California (Eichorn, n.p.) and New York City (Taylor, n.p.) boys. Likewise, the average heat production was lower for girls from New York (Davenport *et al.*, 1939), and Arizona (Thompson, n.p.) than for girls from California (Eichorn, n.p.).

INFLUENCE OF ECONOMIC BACKGROUND

As indicated in section IV, average height and weight of children of a given age was markedly different for children measured by several investigators within the same locality. The socioeconomic background of the children measured differed considerably and pointed, to the possibility that environmental conditions might have influenced the size of the children. Thus, the available data from three investigators were separated into groups reflecting differences in economic levels.

The average height, weight, and basal heat production (Calories per unit of surface area) in relation to age for children representing different economic backgrounds in New York City (Tay-

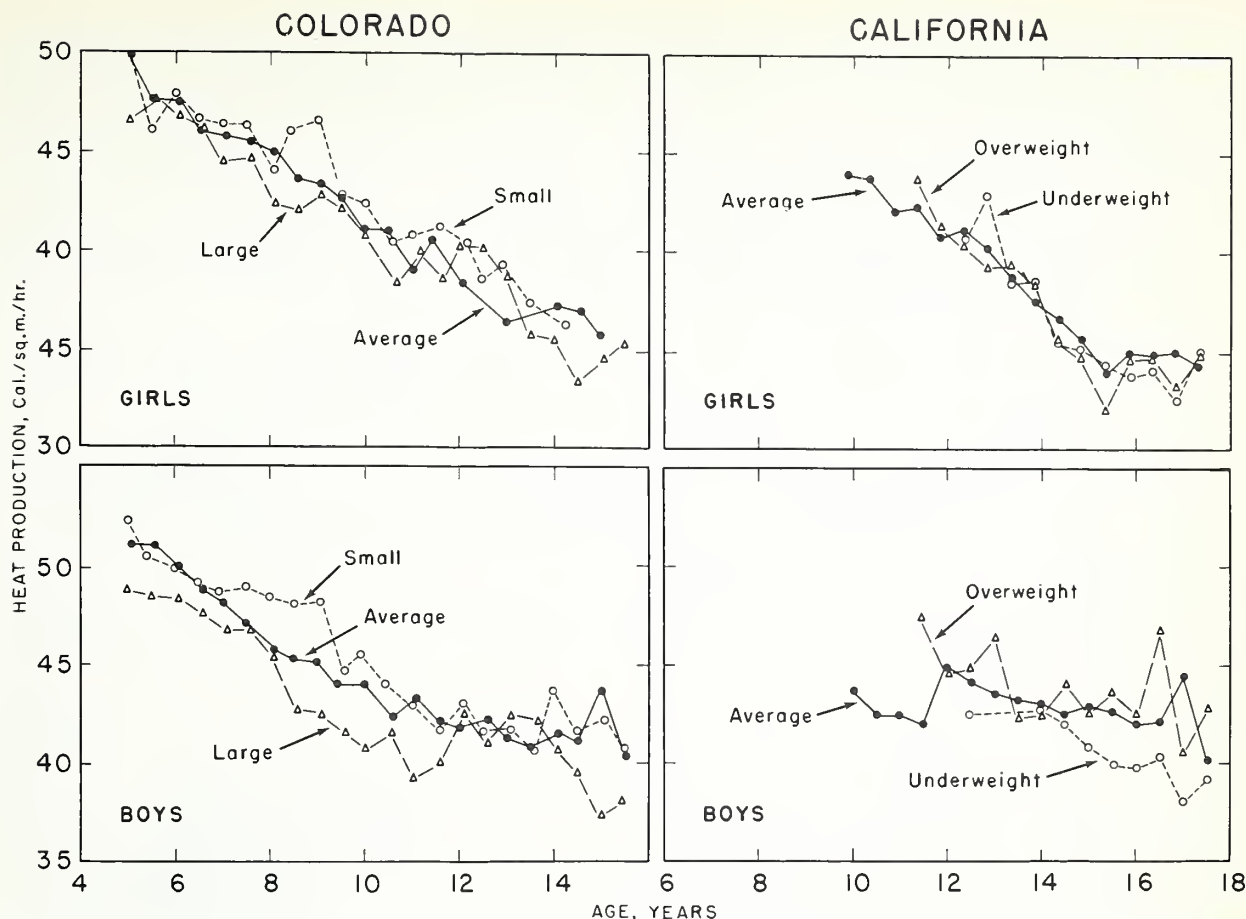


FIGURE 34.—CHILDREN IN DIFFERENT HEIGHT-WEIGHT-AGE DIVISIONS: Basal heat production per unit of body surface.

Colorado children are divided into "small," "average," or "large" on the basis of height and weight for age, and California children as "overweight," "average," or "underweight." Data for Colorado, from Lewis, Kinsman, and Iliff (1937) and Duval (1942); for California, from Eichorn (n.p.). Numerical values are presented in tables 18 and 19.

lor, n.p.) are shown in figure 36. Both the boys and girls from institutions (considered a low economic level) were decidedly shorter and weighed less than the children of the same age from the Teachers' College schools and the parochial school (considered to be on a higher economic level). The boys attending the parochial school were, on the average, shorter and weighed less than those from the Teachers' College schools. However, there was no consistent difference in the size of the girls from these schools throughout the entire age span. Heat production per unit of body surface also was lower in the boys from the institutions but no consistent difference between groups was found in the girls.

Data by Eichorn (n.p.) on California boys and girls were separated into three socio-economic classes on the basis of standard scores (an average of standard scores for three ratings of home and neighborhood). Children with socio-economic scores between 45 and 55 were considered to have an average socio-economic status, while children

with scores below 45 were designated as having a poorer than average status and children above 55 had a better than average status. Figure 37 shows the average height, weight, and basal heat production (Calories per unit of surface area) in relation to age for the three socio-economic classes. Boys with poorer than average socio-economic scores were, on the average, slightly shorter but weighed approximately the same as those in other socio-economic classes, whereas girls with poorer than average socio-economic scores were decidedly heaviest. Heat production per unit of body surface fluctuated considerably; however, boys with better than average socio-economic scores had a slightly higher metabolic rate than the other groups.

The percentage distribution of children in the five height-weight-age divisions differed for the groups reflecting different economic levels. Groups reflecting a low economic level tended to have a greater percentage of overweight and small children than the groups reflecting a higher

economic level. This is shown in table 20 from data by Taylor (n.p.) on New York City children from institutions (low economic level) and from the Teachers' College schools (higher economic level); from data by Morse (n.p.) on Chicago boys from the Settlement House and Boys' Club

as compared with boys from the Hyde Park Neighborhood House or sons of University staff (reflecting a higher economic level); and from data by Eichorn (n.p.) in which the percentage distribution of three socio-economic classes of California children are compared.

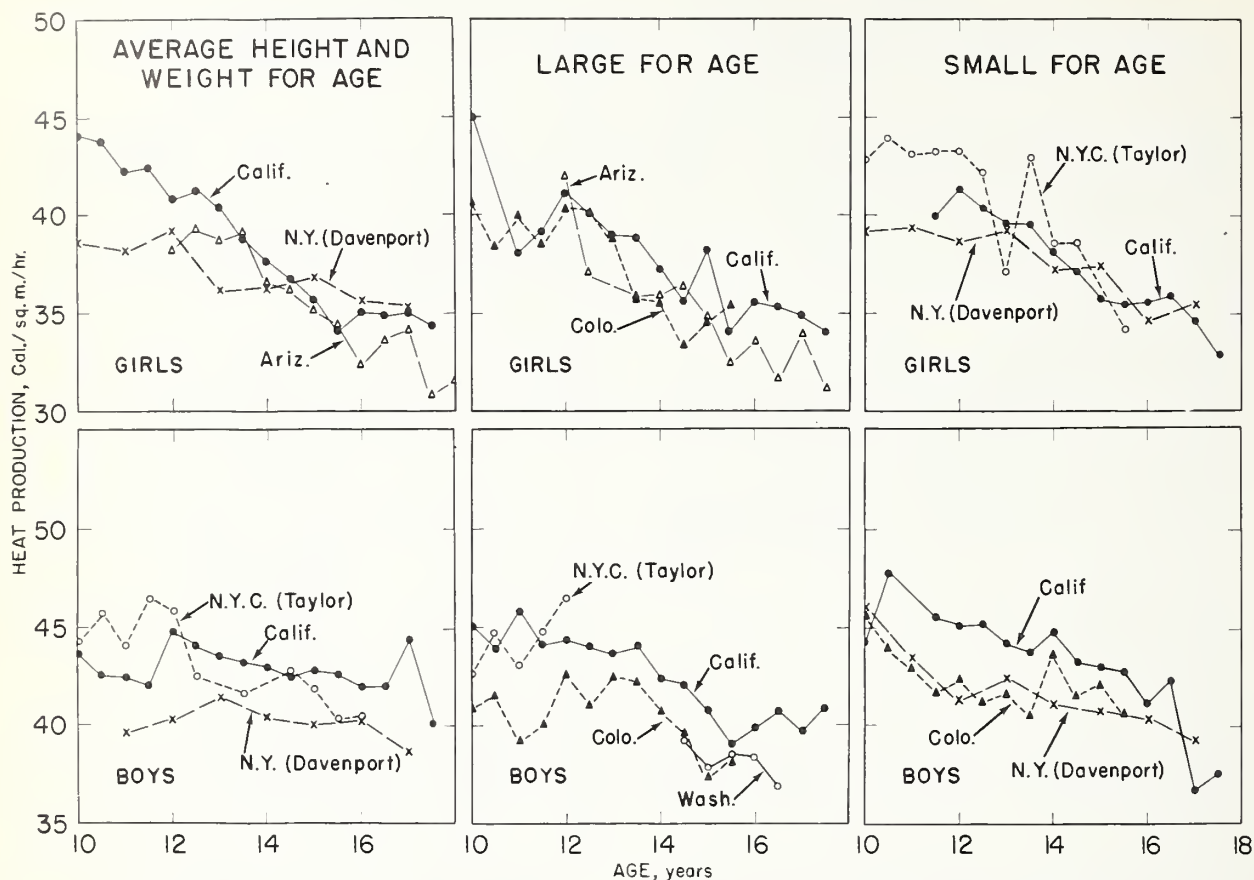


FIGURE 35.—CALIFORNIA BOYS AND GIRLS IN THE "AVERAGE," "LARGE," AND "SMALL" HEIGHT-WEIGHT-AGE DIVISIONS COMPARED WITH SIMILAR DIVISIONS OF CHILDREN IN OTHER LOCALITIES: Basal heat production per unit of body surface.

Data for New York City, from Taylor (n.p.); for New York, from Davenport, Renfroe, and Hallock (1941); for Colorado, from Lewis, Kinsman, and Iliff (1937) and Duval (1942); for Arizona, from Thompson (n.p.); for Washington, from Esselbaugh (n.p.); for California, from Eichorn (n.p.). Numerical values are presented in tables 18 and 19.

BOYS

GIRLS

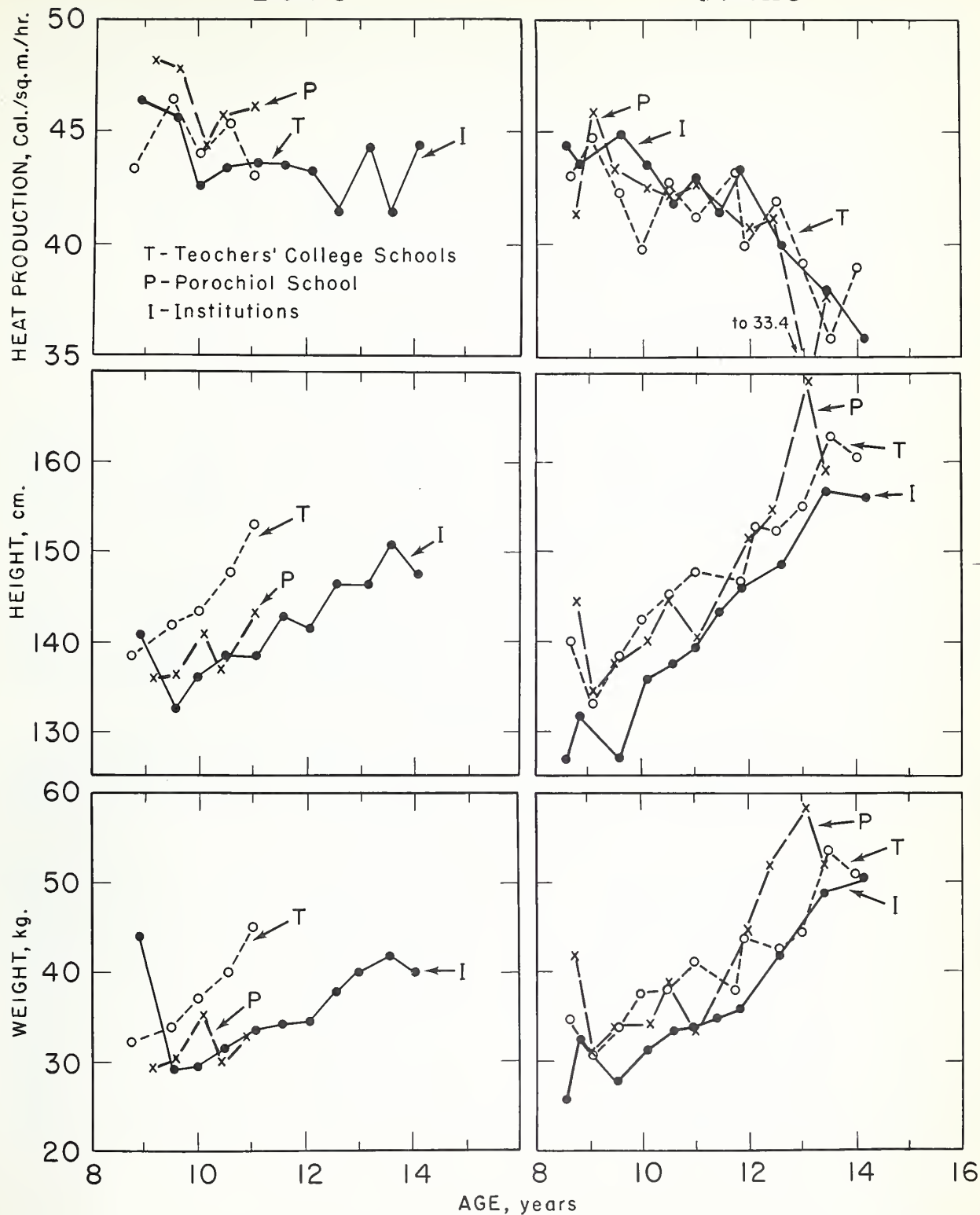


FIGURE 36.—THREE GROUPS OF NEW YORK CITY CHILDREN, 8 TO 14 YEARS OLD, REFLECTING DIFFERENT ECONOMIC LEVELS: Weight, height, and basal heat production per unit of body surface.

Data from Taylor (n.p.).

TABLE 18.—BOYS: *Average heat production*

Age in years	Average					Large					Small	
	Measure- ments	Weight	Height	Heat production		Measure- ments	Weight	Height	Heat production		Measure- ments	Weight
	New York City (Taylor n.p.)											
	<i>Number</i>	<i>Kg.</i>	<i>Cm.</i>	<i>Cal./hr.</i>	<i>Cal./sq. m./hr.</i>	<i>Number</i>	<i>Kg.</i>	<i>Cm.</i>	<i>Cal./hr.</i>	<i>Cal./sq. m./hr.</i>	<i>Number</i>	<i>Kg.</i>
9½	11	31.6	137.9	51.8	46.9	5	37.0	144.7	54.9	45.0	8	27.4
10	16	33.2	139.8	50.5	44.2	6	40.0	146.7	54.4	42.6	2	26.3
10½	4	33.8	139.6	52.2	45.7	4	39.7	149.7	57.8	44.7	6	29.3
11	6	35.1	145.3	52.7	44.0	5	43.8	152.6	59.2	43.0	4	31.0
11½	5	39.1	147.3	59.3	46.5	3	53.5	153.8	66.8	44.7	9	31.5
12	6	42.5	149.2	60.9	45.8	4	51.4	156.4	69.0	46.4	10	33.2
	New York City (Topper and Mulier, 1929a, 1929b, 1932)											
10	0					0					5	24.2
12	0					0					4	27.5
13	2	41.5	158.0	57.5	41.8	0					2	31.0
13½	0					1	69.0	165.0	67.0	38.1	6	33.9
	New York (Davenport, Renfroe, and Hallock, 1939)											
10	1	32.8	137.0	49.8	44.5	0					8	25.6
11	4	35.5	141.5	46.8	39.6	0					16	28.6
12	6	39.6	146.8	51.5	40.3	0					25	30.4
13	9	42.9	152.4	56.1	41.4	0					28	33.0
14	10	48.4	159.4	59.6	40.5	0					30	37.3
15	10	53.6	165.0	63.0	40.0	0					25	41.2
16	4	54.9	168.8	65.4	40.3	1	60.0	177.0	58.5	33.4	23	47.1
17	5	60.3	170.6	66.2	38.9	0					11	47.3
	New York (Webster, Harrington, and Wright, 1941)											
12	9	40.3	149.6	56.4	43.6	0					1	29.7
12½	9	40.6	152.1	54.9	41.7	1	45.0	157.5	62.9	44.6	2	31.0
13	3	46.8	156.4	56.2	39.2	2	52.8	161.4	67.0	43.6	4	36.0
13½	6	46.2	158.4	60.4	42.2	1	55.2	167.6	75.3	46.8	4	38.4
14	6	50.5	161.3	62.4	41.7	1	58.4	170.2	82.7	49.6	1	35.2
14½	7	53.1	164.0	70.5	45.4	1	63.8	174.0	81.6	46.6	2	37.7
15	4	57.2	168.6	70.5	43.1	2	66.6	173.7	74.6	42.0	2	41.0
15½	4	58.2	169.0	72.9	44.1	2	68.0	175.9	77.0	42.4	2	43.6
	Illinois (Morse, n.p.)											
11½	4	33.7	144.9	52.4	44.6	2	46.3	160.4	69.2	47.4	2	32.0
12½	7	38.4	151.3	58.2	45.2	1	43.0	158.1	56.2	40.4	3	34.5
14	4	49.0	162.6	66.8	44.2	4	54.4	171.5	75.0	46.2	5	42.9
14½	6	50.9	163.5	68.2	44.4	3	65.5	177.9	76.4	42.3	2	43.5
16	4	59.2	171.2	69.8	41.2	0					3	49.4
	Colorado (Lewis, Kinsman, and Iliff (1937); Duval, 1942)											
5	28	19.3	111.4	39.4	51.2	8	20.6	116.0	39.9	48.9	5	17.7
5½	27	20.3	114.6	40.9	51.1	10	22.8	120.2	42.3	48.5	9	18.0
6	25	21.3	117.6	41.8	50.1	14	23.6	123.6	43.6	48.4	4	18.6
6½	27	22.5	120.8	42.5	48.9	11	25.5	127.4	45.3	47.6	3	18.1
7	27	23.7	124.1	43.7	48.2	13	26.5	129.5	45.7	46.7	4	18.6
7½	23	25.7	127.7	45.0	47.1	10	29.0	133.1	48.6	46.8	6	21.7
8	30	27.4	130.8	45.7	45.8	10	30.6	136.0	48.9	45.4	7	21.8
8½	30	28.7	133.3	46.8	45.3	10	31.1	138.8	47.1	42.7	7	22.8
9	19	30.3	136.0	48.4	45.2	7	33.5	141.8	49.1	42.5	10	24.5
9½	19	31.2	137.3	48.2	44.0	7	35.8	144.5	50.3	41.6	8	25.1
10	18	32.3	140.5	49.8	44.0	5	37.0	146.4	50.6	40.8	7	26.9
10½	13	33.5	142.0	48.9	42.3	9	38.1	148.9	52.7	41.5	9	28.1
11	14	35.9	144.8	52.5	43.4	4	41.8	152.4	52.5	39.2	9	28.6
11½	9	37.6	146.8	52.5	42.1	6	42.0	154.9	54.1	40.0	7	30.1
12	12	37.7	150.6	53.1	41.8	4	44.8	156.1	59.4	42.6	3	30.6
12½	8	41.5	151.7	56.0	42.2	6	48.6	161.2	61.0	41.0	9	33.6
13	13	41.5	154.9	55.6	41.2	4	53.4	165.0	66.6	42.5	6	35.2
13½	9	43.0	159.0	56.7	40.8	2	61.8	172.4	73.0	42.2	4	36.7
14	7	45.4	161.9	60.1	41.5	4	60.0	173.1	69.9	40.7	5	39.1
14½	6	52.6	167.4	65.0	41.1	2	66.6	175.6	71.8	39.6	5	40.5
15	4	53.3	168.5	69.8	43.7	2	55.4	175.2	62.6	37.4	3	44.4
15½	3	51.8	170.4	64.4	40.4	4	59.9	176.6	66.2	38.1	2	47.9

for five height-weight-age divisions

Small—Continued				Overweight				Underweight				Total Measure- ments	
Height	Heat production			Measure- ments	Weight	Height	Heat production	Measure- ments	Weight	Height	Heat production		
New York City (Taylor, n.p.)—Continued													
<i>Cm.</i>	<i>Cal./hr.</i>	<i>Cal./sq. m./hr.</i>	<i>Number</i>	<i>Kg.</i>	<i>Cm.</i>	<i>Cal./hr.</i>	<i>Cal./sq. m./hr.</i>	<i>Number</i>	<i>Kg.</i>	<i>Cm.</i>	<i>Cal./hr.</i>	<i>Cal./sq. m./hr.</i>	<i>Number</i>
130.7	47.8	47.7	1	31.5	133.5	48.6	45.0	1	32.0	147.3	55.0	47.4	26
129.8	41.8	42.6	2	33.5	135.8	54.0	48.4	1	35.7	148.3	53.1	42.8	27
135.3	47.3	44.7	3	38.4	135.1	49.2	41.9	2	28.8	140.8	47.2	43.9	19
134.5	48.4	44.7	4	40.9	139.2	51.8	42.0	0	-----	-----	-----	-----	19
138.5	50.4	45.4	3	42.9	143.0	55.9	43.2	0	-----	-----	-----	-----	20
140.2	50.4	44.0	7	49.4	145.4	59.7	43.0	0	-----	-----	-----	-----	27
New York City (Topper and Mulier, 1929a, 1929b, 1932)—Continued													
129.8	40.3	42.6	7	52.9	143.1	50.3	36.1	0	-----	-----	-----	-----	12
136.2	43.2	41.7	13	51.3	143.8	51.0	36.5	0	-----	-----	-----	-----	17
134.5	49.2	45.7	5	62.8	153.6	62.9	39.2	1	45.0	165.0	56.0	38.1	10
135.5	48.5	43.0	3	49.3	150.0	62.3	44.0	0	-----	-----	-----	-----	10
New York (Davenport, Renfroe, and Hallock, 1939)—Continued													
125.1	43.4	46.1	2	35.2	136.6	51.6	44.8	0	-----	-----	-----	-----	11
132.0	44.7	43.5	4	36.7	138.9	49.0	41.3	1	28.3	145.0	41.1	37.4	25
136.4	44.7	41.4	3	37.2	142.0	50.9	42.0	2	30.2	147.5	47.2	41.5	36
140.3	48.4	42.5	4	39.6	144.3	54.4	43.1	1	31.4	151.7	41.4	35.1	42
145.5	50.6	41.2	1	47.8	152.0	56.5	39.8	0	-----	-----	-----	-----	41
151.4	53.9	40.8	1	53.3	157.0	62.0	40.8	0	-----	-----	-----	-----	36
158.1	58.4	40.5	0	-----	-----	-----	-----	1	47.9	170.7	66.5	43.2	29
158.4	57.0	39.4	1	59.4	164.0	64.6	39.2	1	52.3	171.7	64.6	40.4	18
New York (Webster, Harrington, and Wright, 1941)—Continued													
136.8	53.0	49.6	0	-----	-----	-----	-----	2	32.2	146.7	50.0	43.0	12
141.0	49.8	44.6	2	41.7	146.4	52.4	40.4	0	-----	-----	-----	-----	14
145.6	53.4	44.2	0	-----	-----	-----	-----	1	34.5	152.4	49.2	39.7	10
149.0	56.4	44.6	2	48.8	152.9	57.2	40.2	0	-----	-----	-----	-----	13
150.2	49.0	39.8	3	54.8	158.4	59.9	39.1	0	-----	-----	-----	-----	11
150.6	61.7	48.6	1	51.4	153.0	54.9	37.6	0	-----	-----	-----	-----	11
155.8	60.0	44.6	3	62.5	162.7	67.7	40.8	0	-----	-----	-----	-----	11
158.3	64.2	45.8	2	60.4	161.4	66.7	41.0	0	-----	-----	-----	-----	10
Illinois (Morse, n.p.)—Continued													
141.6	52.7	46.6	1	33.9	137.8	53.8	47.2	1	37.6	156.5	54.4	41.5	10
142.9	54.7	46.7	1	50.9	149.0	66.6	46.6	0	-----	-----	-----	-----	12
153.5	58.0	42.5	2	53.0	158.8	66.6	44.0	1	47.7	168.6	61.4	40.4	16
156.8	68.5	49.1	1	51.7	151.3	72.4	49.6	1	44.9	166.1	65.4	45.1	13
163.0	68.6	45.3	2	64.2	165.0	68.5	40.4	1	62.3	179.7	71.5	39.9	10
Colorado (Lewis, Kinsman, and Iliff (1937); Duval, 1942)—Continued													
107.1	37.7	52.4	0	-----	-----	-----	-----	8	17.7	112.6	38.2	51.0	49
110.2	37.4	50.5	0	-----	-----	-----	-----	8	19.5	117.0	40.7	50.8	54
113.1	38.2	49.8	0	-----	-----	-----	-----	11	20.1	119.3	39.7	48.5	54
116.1	38.0	49.2	1	24.3	116.6	42.3	48.3	8	21.5	122.2	41.7	48.6	50
118.6	39.0	48.9	1	24.9	120.2	45.9	50.8	4	22.6	125.4	43.8	49.1	49
121.3	42.1	49.0	1	27.2	122.7	45.6	48.0	5	24.2	129.3	43.8	46.5	45
123.9	42.4	48.5	1	30.8	125.9	48.7	47.5	6	25.5	132.7	44.2	45.2	54
125.6	43.3	48.1	0	-----	-----	-----	-----	6	25.4	134.0	44.1	44.9	53
128.3	45.3	48.2	1	34.5	135.2	48.7	43.1	5	25.8	135.3	46.6	46.6	42
131.2	43.1	44.7	2	38.8	139.3	56.4	46.2	12	28.2	139.5	47.0	44.4	48
133.0	45.5	45.5	2	39.2	140.8	53.9	43.6	6	29.9	142.7	47.5	42.8	38
135.1	45.6	44.0	2	36.6	139.8	51.6	43.4	7	30.6	143.8	47.6	42.4	40
137.4	45.3	43.0	0	-----	-----	-----	-----	5	31.5	146.5	48.6	42.2	32
139.2	45.4	41.7	0	-----	-----	-----	-----	5	32.7	147.9	48.8	41.4	27
141.2	47.7	43.0	0	-----	-----	-----	-----	4	33.7	150.7	46.2	38.2	23
143.9	48.7	41.5	0	-----	-----	-----	-----	5	35.0	152.5	50.7	40.8	28
145.4	50.2	41.7	0	-----	-----	-----	-----	1	34.0	151.6	52.1	42.6	24
147.8	50.4	40.6	1	59.9	160.5	68.3	42.2	0	-----	-----	-----	-----	16
150.4	56.4	43.7	1	60.3	162.6	66.2	40.2	2	45.8	166.0	60.2	40.7	19
153.8	55.2	41.6	0	-----	-----	-----	-----	4	47.0	169.3	59.1	39.0	17
156.1	59.0	42.2	0	-----	-----	-----	-----	1	47.4	168.7	60.0	39.5	10
160.7	60.2	40.7	0	-----	-----	-----	-----	2	50.6	174.0	63.9	39.9	11

TABLE 18.—BOYS: *Average heat production*

Age in years	Average					Large					Small	
	Measure- ments	Weight	Height	Heat production		Measure- ments	Weight	Height	Heat production		Measure- ments	Weight
	Washington (Esselbaugh, n.p.)											
	<i>Number</i>	<i>Kg.</i>	<i>Cm.</i>	<i>Cal./hr.</i>	<i>Cal./sq. m./hr.</i>	<i>Number</i>	<i>Kg.</i>	<i>Cm.</i>	<i>Cal./hr.</i>	<i>Cal./sq. m./hr.</i>	<i>Number</i>	<i>Kg.</i>
14½	12	54.5	168.0	67.1	41.6	10	67.0	178.7	71.8	39.2	3	46.1
15	10	55.0	171.0	67.0	41.2	4	62.8	177.9	67.3	37.8	4	49.9
15½	9	58.0	169.7	66.8	40.0	7	67.0	178.9	70.8	38.5	6	48.4
16	12	61.0	171.6	63.4	36.9	15	75.9	181.2	74.9	38.3	1	49.5
16½	2	58.5	171.9	65.0	38.5	5	67.6	179.5	68.3	36.8	0	-----
	California (Eichorn, n.p.)											
10	6	32.7	140.2	49.4	43.7	6	41.2	150.9	59.2	45.0	1	27.4
11½	7	36.6	146.9	51.6	41.9	3	42.8	155.0	60.5	44.1	4	32.2
12	16	40.0	150.0	58.2	44.8	5	43.3	158.0	61.5	44.3	11	32.0
12½	22	41.4	152.0	58.7	44.1	7	48.4	159.9	64.8	44.0	9	34.1
13	25	42.8	155.5	59.8	43.5	8	51.2	164.4	67.3	43.6	11	34.4
13½	18	44.9	159.8	62.0	43.2	8	55.4	170.0	72.0	44.0	10	37.8
14	19	47.7	162.0	63.9	43.0	9	57.5	172.5	71.3	42.3	13	40.0
14½	18	51.0	165.7	66.2	42.5	11	60.9	175.6	73.7	42.1	12	43.0
15	19	52.3	166.8	67.4	42.8	14	65.0	176.7	73.3	40.7	13	44.5
15½	17	55.3	170.9	70.1	42.6	12	65.3	179.2	71.4	39.0	6	49.0
16	14	59.1	172.6	71.4	42.0	13	65.6	180.6	73.4	39.9	8	49.4
16½	12	60.4	174.1	72.7	42.0	11	68.5	181.8	76.7	40.7	2	49.6
17	9	60.6	174.2	77.1	44.5	10	69.0	181.6	75.0	39.7	4	51.3
17½	6	61.7	176.9	71.0	40.1	9	69.7	183.1	78.2	40.9	3	51.7

TABLE 19.—GIRLS: *Average heat production*

Age in years	Average					Large					Small	
	Measure- ments	Weight	Height	Heat production		Measure- ments	Weight	Height	Heat production		Measure- ments	Weight
	Massachusetts (Talbot, Wilson, and Worcester, 1937)											
11½-----	<i>Number</i> 4	<i>Kg.</i> 43.4	<i>Cm.</i> 150.0	<i>Cal./hr.</i> 60.7	<i>Cal./sq. m./hr.</i> 45.3	<i>Number</i> 4	<i>Kg.</i> 53.0	<i>Cm.</i> 160.4	<i>Cal./hr.</i> 67.7	<i>Cal./sq. m./hr.</i> 44.0	<i>Number</i> 1	<i>Kg.</i> 33.3
	New York City (Taylor, n.p.)											
8½-----	1	27.2	133.9	41.7	40.9	5	36.0	140.9	50.7	42.8	3	23.4
9-----	5	28.4	132.5	48.2	47.0	3	36.9	138.8	50.3	42.4	1	26.0
9½-----	12	31.8	135.5	48.0	43.9	7	38.2	144.3	51.4	41.5	5	27.0
10-----	14	33.0	138.4	49.2	43.5	6	39.8	148.5	52.7	40.9	8	26.5
10½-----	8	33.6	140.8	49.0	42.3	7	43.9	150.2	57.8	42.5	6	28.6
11-----	9	36.7	143.3	52.6	43.4	4	47.7	152.8	56.3	39.6	9	30.3
11½-----	9	38.5	148.1	52.6	41.4	8	51.7	156.1	61.4	41.3	12	31.3
12-----	11	41.2	150.6	56.0	42.4	7	51.2	159.9	59.6	39.4	5	33.4
12½-----	10	44.5	154.2	57.0	41.1	1	55.3	161.2	51.1	32.5	3	35.4
13-----	1	47.6	156.5	65.6	45.2	3	56.8	165.4	58.7	36.2	2	37.6
14-----	3	49.6	159.0	54.3	36.5	2	59.0	168.8	68.0	40.7	1	36.0
	New York City (Topper and Mulier, 1929a, 1929b, 1932)											
10-----	2	27.5	137.0	42.5	40.8	0	-----	-----	-----	-----	7	24.9
11-----	7	32.9	146.3	49.1	41.9	0	-----	-----	-----	-----	6	29.1
12-----	6	38.4	151.8	59.0	46.0	0	-----	-----	-----	-----	5	30.9
12½-----	5	42.1	153.8	56.9	42.1	0	-----	-----	-----	-----	6	34.7
13-----	4	45.2	156.2	60.0	42.6	0	-----	-----	-----	-----	7	37.7
13½-----	2	42.2	157.0	60.6	44.0	1	50.3	165.0	60.0	39.0	5	41.5
14-----	1	60.0	160.0	57.0	35.2	0	-----	-----	-----	-----	6	39.3
	New York (Davenport, Renfroe, and Hallock, 1939)											
10-----	2	29.2	139.8	41.8	38.6	1	36.8	145.7	49.5	40.2	11	24.6
11-----	8	33.3	143.2	44.3	38.2	0	-----	-----	-----	-----	15	26.8
12-----	10	38.1	149.3	49.7	39.2	0	-----	-----	-----	-----	26	31.0
13-----	8	43.2	155.7	49.8	36.2	0	-----	-----	-----	-----	28	36.1
14-----	9	47.3	158.3	52.4	36.3	1	53.0	165.9	70.3	44.8	24	39.5
15-----	8	50.9	159.5	55.3	36.8	2	56.4	167.6	70.0	42.8	20	42.6
16-----	7	52.1	160.3	54.1	35.6	0	-----	-----	-----	-----	11	45.2
17-----	4	52.6	161.5	54.3	35.3	0	-----	-----	-----	-----	7	44.3

for five height-weight-age divisions—Continued

Small—Continued				Overweight				Underweight				Total Measure- ments	
Height	Heat production			Measure- ments	Weight	Height	Heat production		Measure- ments	Weight	Height		Heat production
Washington (Esselbaugh, n.p.)—Continued													
<i>Cm.</i>	<i>Cal./hr.</i>	<i>Cal./sq. m./hr.</i>	<i>Number</i>	<i>Kg.</i>	<i>Cm.</i>	<i>Cal./hr.</i>	<i>Cal./sq. m./hr.</i>	<i>Number</i>	<i>Kg.</i>	<i>Cm.</i>	<i>Cal./hr.</i>	<i>Cal./sq. m./hr.</i>	<i>Number</i>
154.5	61.4	43.3	0					0					25
159.8	59.0	39.5	4	58.0	161.8	63.2	39.3	5	53.3	176.2	62.8	37.4	27
159.4	61.2	41.6	2	74.9	171.8	74.2	40.2	4	56.3	177.1	68.4	40.7	28
165.7	64.3	41.9	4	77.2	170.4	72.0	38.4	2	57.7	179.8	72.6	41.8	34
			1	86.6	172.7	87.4	43.5	2	53.0	176.4	56.2	33.8	10
California (Eichorn, n.p.)—Continued													
135.4	45.5	44.2	0					1	35.4	147.5	55.3	44.6	14
140.8	51.5	45.5	2	35.2	138.4	54.8	47.1	0					16
141.0	51.0	45.1	6	41.6	144.4	57.4	44.6	0					38
142.9	53.1	45.2	4	44.2	144.8	59.1	44.9	3	38.1	155.3	55.5	42.3	45
144.5	52.5	44.2	5	47.6	148.6	63.9	46.4	0					49
149.1	55.5	43.8	6	51.9	154.4	62.6	42.3	1	49.0	169.5	73.6	47.5	43
151.8	58.9	44.8	3	55.1	155.2	64.4	42.3	1	53.0	172.8	69.1	42.7	45
155.4	59.8	43.3	3	56.1	155.1	72.0	47.3	6	52.5	172.6	67.9	41.9	50
158.1	61.0	43.0	3	68.9	165.7	74.9	42.6	4	56.1	177.7	69.6	40.8	53
162.1	64.5	42.8	2	55.6	161.0	69.6	44.2	5	55.6	176.6	67.3	39.9	42
163.6	62.6	41.2	3	68.8	169.4	76.1	42.5	5	57.1	177.6	68.2	39.8	43
166.1	65.2	42.3	2	59.3	163.8	77.0	46.8	7	57.5	178.4	69.4	40.3	34
167.5	57.8	36.8	2	67.6	170.4	72.6	40.6	3	58.3	189.2	66.4	38.0	28
168.7	59.7	37.6	2	61.6	166.0	72.4	42.8	4	63.3	182.2	71.8	39.2	24

for five height-weight-age divisions

Small—Continued			Overweight					Underweight					Total Measure- ments
Height	Heat production		Measure- ments	Weight	Height	Heat production		Measure- ments	Weight	Height	Heat production		
Massachusetts (Talbot, Wilson, and Worcester, 1937)—Continued													
<i>Cm.</i> 140.5	<i>Cal./hr.</i> 56.6	<i>Cal./sq. m./hr.</i> 49.2	<i>Number</i> 1	<i>Kg.</i> 34.7	<i>Cm.</i> 135.2	<i>Cal./hr.</i> 54.3	<i>Cal./sq. m./hr.</i> 47.6	<i>Number</i> 0	-----	-----	-----	-----	10
New York City (Taylor, n.p.)—Continued													
124.6	40.3	44.4	2	36.7	130.1	48.7	43.9	0	-----	-----	-----	-----	11
129.6	41.9	43.2	2	32.5	131.4	50.6	47.1	1	26.2	134.0	45.0	45.0	12
127.6	44.1	44.9	3	33.6	130.4	48.0	43.1	0	-----	-----	-----	-----	27
130.3	42.1	42.8	3	40.0	137.8	49.9	41.1	0	-----	-----	-----	-----	31
132.6	45.1	43.9	5	42.5	139.5	52.8	41.9	0	-----	-----	-----	-----	26
135.9	46.5	43.1	1	48.1	146.3	57.6	41.1	1	38.7	153.5	49.3	37.6	24
137.4	47.4	43.3	15	46.7	144.3	56.5	41.8	0	-----	-----	-----	-----	44
140.3	49.7	43.3	7	52.0	150.1	59.2	40.6	0	-----	-----	-----	-----	30
141.5	49.8	42.2	3	51.1	151.1	56.2	38.9	0	-----	-----	-----	-----	17
146.6	46.4	37.1	4	51.3	151.6	58.6	40.1	1	44.4	165.9	53.9	36.9	11
145.4	47.5	38.6	4	60.1	157.2	62.5	38.8	1	45.1	165.0	57.7	39.0	11
New York City (Topper and Mulier, 1929a, 1929b, 1932)—Continued													
130.6	38.0	39.5	6	52.1	142.8	49.2	35.0	1	25.0	139.0	38.5	38.1	16
136.0	41.8	39.5	9	50.5	144.4	50.7	36.5	3	30.0	146.7	43.4	38.5	25
139.8	45.6	41.3	19	55.0	146.5	55.9	38.6	1	34.0	152.0	62.0	50.8	31
140.1	51.2	43.7	2	54.4	154.5	64.1	42.2	0	-----	-----	-----	-----	13
145.6	57.9	46.7	8	57.1	153.1	67.1	39.9	1	36.0	154.0	63.8	50.2	20
149.0	57.3	43.6	5	58.9	153.0	60.9	39.4	2	42.2	161.5	63.4	45.4	15
153.8	55.7	42.5	6	65.6	159.3	61.1	36.5	5	44.7	162.0	60.1	41.8	18
New York (Davenport, Renfroe, and Hallock, 1939)—Continued													
126.5	36.7	39.3	1	33.0	129.5	39.7	36.8	1	25.8	135.5	37.6	37.6	16
130.9	39.1	39.3	3	35.5	135.0	46.6	40.7	0	-----	-----	-----	-----	26
136.9	42.3	38.7	4	39.6	139.3	48.2	39.4	0	-----	-----	-----	-----	40
143.7	47.4	39.3	8	44.5	145.1	51.0	38.5	0	-----	-----	-----	-----	44
146.9	47.3	37.3	9	50.9	150.7	54.5	37.7	1	44.3	160.0	45.7	32.2	44
148.5	49.6	37.5	9	54.1	153.8	53.5	35.6	1	46.3	162.1	45.2	31.0	40
150.6	47.7	34.7	7	54.4	154.2	52.8	35.0	2	48.8	162.7	57.6	38.3	27
149.6	48.0	35.5	4	57.4	154.0	59.3	38.5	0	-----	-----	-----	-----	15

TABLE 19.—GIRLS: *Average heat production for*

Age in years	Average					Large					Small	
	Measure- ments	Weight	Height	Heat production		Measure- ments	Weight	Height	Heat production		Measure- ments	Weight
New York (Webster, Harrington, and Wright, 1941)												
12½	Number 5	Kg. 43.2	Cm. 153.4	Cal./hr. 55.7	Cal./sq. m./hr. 41.1	Number 0	Kg.	Cm.	Cal./hr.	Cal./sq. m./hr.	Number 4	Kg. 31.9
Ohio (McKay, 1930)												
16	3	53.9	160.7	53.6	34.5	0					2	44.5
17	6	58.8	164.8	61.7	37.5	2	63.4	167.0	58.4	34.2	3	46.5
17½	13	53.7	161.8	53.8	34.5	2	67.6	170.0	66.4	37.3	5	48.3
Michigan (Hoobler, n.p.)												
13	2	42.8	157.0	61.2	44.4	5	51.4	163.0	60.9	39.7	1	39.4
13½	6	46.4	157.6	59.0	41.2	4	52.6	164.0	63.0	40.5	2	42.2
14	5	49.3	158.3	58.2	39.4	6	56.4	166.2	63.0	38.8	2	39.7
14½	6	52.9	160.6	60.2	39.2	5	60.0	167.3	64.0	38.2	0	
15	11	54.5	162.2	62.8	40.2	8	64.1	167.3	67.0	39.0	0	
15½	9	56.2	162.2	60.3	37.9	5	61.2	168.3	63.5	37.6	1	52.2
16	8	55.3	161.7	60.1	38.2	5	61.3	169.0	64.0	38.0	0	
16½	8	55.9	163.2	57.5	36.1	2	56.5	166.7	62.6	38.6	1	47.7
17	6	58.0	163.6	57.6	35.6	0					4	48.6
Kansas (Harrison, n.p.)												
10	4	28.8	138.6	46.6	44.0	6	37.6	145.8	54.8	44.4	5	25.2
11	7	34.9	144.9	52.3	43.8	3	40.3	152.7	59.2	45.3	4	28.2
14	4	45.9	159.6	52.4	36.4	3	63.0	168.3	59.7	34.8	2	42.8
16	6	52.5	162.7	51.6	33.6	6	62.1	170.1	58.6	34.2	2	46.0
16½	5	54.8	162.3	56.9	36.1	2	63.6	174.0	63.0	34.8	1	48.8
Colorado (Lewis, Kinsman, and Iliff, 1937; Duval, 1942)												
5	15	18.7	109.8	37.4	49.8	12	20.3	116.3	37.7	46.6	5	15.5
5½	14	19.6	113.1	37.3	47.7	16	21.7	119.5	40.5	47.6	4	16.4
6	11	20.5	114.9	38.3	47.5	17	23.4	123.1	41.9	46.8	5	17.5
6½	12	21.4	118.9	38.8	46.1	13	25.8	126.6	44.0	46.2	8	17.3
7	8	22.8	121.8	40.3	45.8	13	26.2	130.2	43.6	44.5	7	19.3
7½	9	23.9	124.8	41.5	45.5	15	29.2	133.5	46.6	44.7	8	20.2
8	13	26.5	128.4	43.8	44.9	11	31.4	137.0	46.6	42.4	4	20.0
8½	12	27.3	131.0	43.7	43.7	13	33.3	139.6	48.0	42.1	3	21.5
9	8	30.0	133.6	45.7	43.4	10	36.8	142.1	51.5	42.8	3	22.9
9½	6	31.2	136.6	46.6	42.7	7	36.1	146.0	51.7	42.2	4	23.7
10	8	34.3	139.4	47.4	41.0	6	39.8	150.9	53.1	40.8	3	22.6
10½	10	35.6	141.9	48.8	41.0	5	39.5	152.2	50.1	38.4	3	24.7
11	4	38.2	144.8	48.6	39.0	5	41.2	155.4	53.9	40.0	2	27.2
11½	5	40.8	148.4	52.7	40.6	3	43.5	160.1	54.4	38.6	4	29.8
12	2	47.1	153.9	54.3	38.4	5	45.5	161.4	58.3	40.3	2	31.4
12½	0					3	48.5	161.8	60.0	40.2	2	32.9
13	1	46.7	160.9	53.3	36.5	5	51.5	165.5	60.2	38.7	3	34.3
13½	0					5	54.0	168.7	57.7	35.8	3	36.4
Arizona (Thompson, n.p.)												
12½	2	48.3	156.0	57.0	39.3	6	54.2	164.4	58.7	37.1	3	32.8
13	7	47.0	158.2	56.1	38.7	0					0	
13½	6	46.5	159.0	56.6	39.1	4	54.5	167.7	57.4	35.8	3	41.7
14	6	50.8	160.7	55.3	36.5	5	54.8	166.1	57.7	35.9	3	40.5
14½	11	51.2	160.9	55.0	36.2	10	56.7	167.4	59.6	36.4	2	46.0
15	6	50.7	162.0	53.5	35.2	6	59.0	170.3	58.7	34.9	1	36.8
15½	6	53.2	161.6	53.4	34.4	6	61.2	171.1	57.1	32.4	4	49.0
16½	4	57.0	163.1	54.0	33.6	7	59.9	167.9	53.0	31.7	2	48.7
17	3	53.2	162.7	53.3	34.2	3	63.3	173.3	59.7	34.0	1	48.0
17½	6	55.5	163.0	49.2	30.9	5	64.9	172.8	55.6	31.3	0	
Washington (Esselbaugh, n.p.)												
14½	12	53.0	160.8	53.0	34.4	1	66.4	168.3	54.4	31.0	1	42.3
15	11	50.0	160.1	54.0	36.0	6	62.3	167.7	55.1	32.3	5	44.0
15½	12	54.5	162.2	52.8	33.6	6	63.1	170.5	54.7	31.5	1	49.1
16	9	55.2	163.7	50.8	31.9	5	69.3	172.3	58.5	32.4	5	48.3
California (Eichorn, n.p.)												
10	4	32.5	138.1	49.3	44.0	5	43.1	150.4	60.4	45.2	1	26.4
11½	5	40.2	147.5	54.6	42.4	5	50.0	156.6	58.5	39.7	3	30.7
12	12	40.4	151.5	53.2	40.8	9	54.0	159.5	63.3	41.2	6	31.6
12½	17	42.8	154.3	56.3	41.2	12	55.2	161.5	62.7	40.0	8	34.2
13	18	45.1	156.6	56.7	40.3	9	55.7	164.5	62.4	39.0	8	35.2
13½	18	47.3	159.0	56.4	38.7	12	61.5	166.4	65.3	38.9	6	38.3
14	24	51.0	160.6	56.9	37.6	8	62.8	166.9	63.2	37.2	8	40.1
14½	18	53.0	161.7	56.8	36.7	7	62.7	167.3	60.8	35.6	4	45.4
15	14	51.6	162.4	54.9	35.7	5	64.2	167.6	66.0	38.3	6	44.0
15½	11	55.0	162.9	53.8	34.0	5	58.9	167.7	56.7	34.1	5	46.7
16	10	53.8	163.4	54.9	35.0	5	59.9	168.7	60.0	35.6	5	47.4
16½	8	53.3	162.8	54.5	34.9	6	59.6	168.3	59.4	35.4	6	46.7
17	11	54.8	162.9	55.3	35.0	6	62.4	168.3	60.0	34.9	1	49.8
17½	3	51.1	163.0	52.7	34.3	6	62.0	168.5	57.9	34.0	3	45.5

five height-weight-age divisions—Continued

Small—Continued				Overweight				Underweight				Total Measure- ments	
Height	Heat production			Measure- ments	Weight	Height	Heat production	Measure- ments	Weight	Height	Heat production		
New York (Webster, Harrington, and Wright, 1941)—Continued													
<i>Cm.</i> 144.2	<i>Cal./hr.</i> 45.6	<i>Cal./sq. m./hr.</i> 39.7	<i>Number</i> 1	<i>Kg.</i> 46.5	<i>Cm.</i> 144.2	<i>Cal./hr.</i> 52.5	<i>Cal./sq. m./hr.</i> 39.1	<i>Number</i> 1	<i>Kg.</i> 35.7	<i>Cm.</i> 154.9	<i>Cal./hr.</i> 48.5	<i>Cal./sq. m./hr.</i> 38.2	<i>Number</i> 11
Ohio (McKay, 1930)—Continued													
155.0	51.1	36.4	3	58.8	157.3	59.1	37.1	2	52.4	170.0	55.4	34.6	10
155.7	53.2	37.3	2	58.6	156.5	55.8	35.4	1	43.8	161.0	50.7	35.3	14
154.8	54.8	38.0	3	70.4	163.7	62.6	35.6	2	54.8	171.0	61.9	37.8	25
Michigan (Hoober, n.p.)—Continued													
152.4	60.6	46.6	3	58.0	150.1	59.9	39.8	0	-----	-----	-----	-----	11
149.9	59.3	44.6	2	53.9	152.1	59.4	40.0	0	-----	-----	-----	-----	14
149.1	47.0	36.3	0	-----	-----	-----	-----	1	40.1	158.4	56.0	41.5	14
-----	-----	-----	6	60.7	156.9	62.0	38.8	2	49.2	164.1	59.4	39.4	19
-----	-----	-----	7	59.0	156.8	62.7	39.7	0	-----	-----	-----	-----	26
157.5	53.0	35.1	5	60.6	157.1	62.5	39.1	0	-----	-----	-----	-----	20
-----	-----	-----	10	61.6	159.2	61.2	37.6	2	48.6	164.0	60.8	40.4	25
154.3	45.8	31.8	6	59.0	156.7	60.8	38.5	1	48.5	165.1	55.1	36.5	18
157.2	54.8	37.6	6	61.0	159.1	60.1	37.2	0	-----	-----	-----	-----	16
Kansas (Harrison, n.p.)—Continued													
132.6	45.5	46.8	1	28.9	131.1	44.6	43.8	2	31.2	143.9	49.3	43.4	18
134.6	45.9	44.6	1	37.5	138.9	49.9	41.7	0	-----	-----	-----	-----	15
154.4	50.4	36.8	0	-----	-----	-----	-----	1	46.6	166.8	47.5	32.4	10
157.4	55.1	39.0	2	61.2	160.0	53.8	33.0	5	49.0	165.1	50.3	33.0	21
158.7	50.4	34.1	2	61.4	159.2	58.6	36.1	5	49.7	167.4	52.0	33.6	15
Colorado (Lewis, Kinsman, and Iliff, 1937; Duval, 1942)—Continued													
105.2	33.8	50.4	2	19.6	107.8	39.8	52.6	8	17.0	111.7	35.1	48.0	42
107.6	32.4	46.0	2	20.3	109.3	39.4	50.8	8	17.8	113.6	36.3	48.2	44
112.2	35.5	47.9	0	-----	-----	-----	-----	6	20.0	120.3	37.8	45.8	39
114.0	34.9	46.6	1	24.2	117.1	39.1	44.4	8	21.7	124.4	39.5	45.1	42
117.1	37.0	46.4	0	-----	-----	-----	-----	5	22.3	125.6	38.7	43.4	33
119.7	38.1	46.3	0	-----	-----	-----	-----	7	24.3	130.5	39.8	41.9	39
121.5	36.5	44.0	0	-----	-----	-----	-----	5	24.2	130.5	41.9	44.4	33
123.9	40.0	46.0	0	-----	-----	-----	-----	5	26.6	135.7	42.1	41.6	33
128.0	42.5	46.6	0	-----	-----	-----	-----	2	30.2	141.3	44.2	40.1	23
129.2	40.0	42.8	2	34.5	135.3	45.5	40.1	3	29.2	142.3	45.1	41.2	22
129.6	38.8	42.3	1	36.2	137.9	48.9	41.8	4	32.8	147.2	48.3	40.8	22
132.7	39.0	40.5	0	-----	-----	-----	-----	4	33.9	150.8	50.9	41.8	22
135.5	41.6	40.8	0	-----	-----	-----	-----	2	38.4	156.3	54.8	41.8	13
139.6	44.7	41.2	0	-----	-----	-----	-----	2	42.3	159.6	52.2	37.6	14
142.1	45.6	40.4	3	47.9	148.4	54.8	39.3	1	44.2	162.8	57.4	39.9	13
144.3	45.0	38.6	3	52.4	152.3	57.7	39.2	3	38.3	160.7	50.2	37.5	11
147.0	47.5	39.4	3	53.2	154.7	57.8	38.5	3	41.6	163.5	57.2	40.5	15
151.1	46.9	37.4	4	59.1	158.5	59.2	37.0	1	42.4	165.9	56.3	39.3	13
Arizona (Thompson, n.p.)—Continued													
141.1	44.9	38.3	0	-----	-----	-----	-----	2	41.1	162.1	55.5	39.8	13
-----	-----	-----	2	70.6	162.8	67.7	38.9	2	40.2	159.8	52.2	38.4	11
152.9	50.4	37.5	2	56.5	155.6	57.6	37.2	1	41.7	161.1	45.4	32.5	16
155.1	51.0	38.2	1	45.6	150.7	53.8	38.9	3	41.7	163.0	54.0	38.4	18
153.0	58.0	41.4	2	57.0	157.6	61.8	39.4	3	46.6	166.9	53.7	35.8	28
155.7	48.6	37.7	1	64.1	164.2	58.4	34.3	5	48.3	165.3	52.3	34.6	19
156.2	51.5	35.2	1	53.5	156.0	51.1	33.7	3	46.9	166.8	50.6	33.7	20
155.1	47.4	32.8	1	67.0	165.4	55.0	31.5	6	49.0	165.7	51.6	33.8	20
156.0	50.8	35.0	0	-----	-----	-----	-----	10	50.2	166.4	56.1	36.3	17
-----	-----	-----	2	58.8	156.2	46.7	29.5	4	51.8	168.5	54.5	34.4	17
Washington (Esselbaugh, n.p.)—Continued													
149.9	47.5	35.7	3	54.7	148.9	57.1	38.6	4	48.2	166.5	54.3	35.8	21
148.7	51.8	38.7	9	58.0	157.4	52.8	33.5	5	49.8	166.0	50.9	33.1	36
158.1	57.9	39.5	4	57.4	148.4	49.9	33.1	4	47.2	169.6	54.5	35.9	27
155.9	48.6	33.6	3	59.7	152.2	58.1	33.0	7	47.8	165.8	50.7	33.6	29
California (Eichorn, n.p.)—Continued													
128.2	42.3	43.6	0	-----	-----	-----	-----	3	-----	-----	-----	-----	13
135.4	43.0	39.9	5	48.1	147.8	60.7	43.8	0	28.7	141.5	46.9	43.3	18
139.7	46.3	41.4	9	45.2	146.1	55.5	41.4	1	39.2	157.0	60.6	45.6	37
144.1	47.9	40.4	11	49.8	150.7	57.3	40.3	3	43.0	161.2	57.7	40.9	51
147.4	48.3	39.6	9	52.3	153.9	58.3	39.3	3	43.9	165.1	62.3	43.0	47
148.7	50.1	39.5	9	54.0	155.2	59.5	39.4	5	44.8	163.5	55.9	38.4	50
151.9	50.3	38.2	7	59.2	156.9	61.0	38.5	3	46.7	165.8	57.7	38.7	50
153.0	51.8	37.2	6	58.4	157.8	56.5	35.6	10	46.7	163.8	52.7	35.5	45
154.3	49.7	35.8	4	60.7	157.0	56.0	34.9	12	48.3	165.6	53.6	35.3	41
154.2	50.5	35.5	4	62.1	160.1	52.6	32.0	9	49.0	165.9	52.6	34.3	33
154.4	50.8	35.6	7	58.9	158.5	55.2	34.6	8	53.0	169.3	54.4	33.8	35
154.4	51.1	35.9	3	66.3	162.9	59.4	34.7	9	53.2	167.2	53.1	34.0	32
158.0	51.6	34.6	5	63.3	160.8	55.6	33.5	5	51.9	167.3	51.4	32.4	28
154.8	46.4	32.9	3	65.6	161.9	59.0	34.8	5	51.4	167.3	54.9	34.9	20

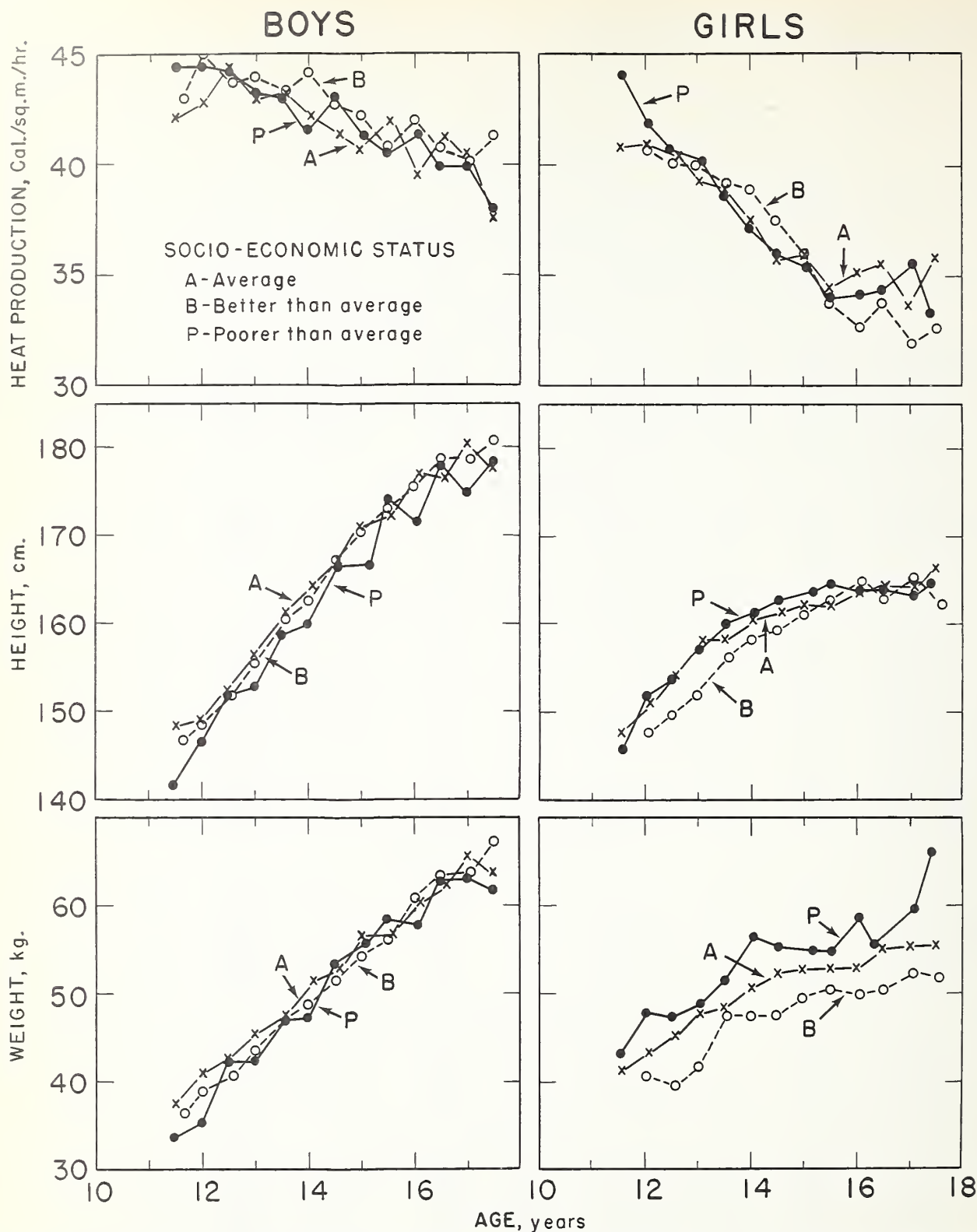


FIGURE 37.—THREE SOCIO-ECONOMIC LEVELS FOR CALIFORNIA CHILDREN, 12 TO 18 YEARS OLD: Weight, height, and basal heat production per unit of body surface.
Data from Eichorn (n.p.).

TABLE 20.—*Influence of economic background on the percentage distribution of children in five height-weight-age divisions*

Location and group reflecting economic background	Boys						Girls					
	Height-weight-age division					Total	Height-weight-age division					Total
	Average	Large	Small	Over-weight	Under-weight		Average	Large	Small	Over-weight	Under-weight	
New York City (Taylor, n.p.):												
Teachers' College Schools	Percent	Percent	Percent	Percent	Percent	Number	Percent	Percent	Percent	Percent	Percent	Number
Parochial school	32.0	56.0	4.0	0	8.0	25	36.0	34.7	10.7	8.0	10.7	75
Institutions	54.1	10.8	24.3	5.4	5.4	37	46.4	28.6	14.3	8.9	1.8	56
	35.4	3.7	46.3	12.2	2.4	82	42.2	4.7	39.1	14.1	0	64
Total ¹	36.2	15.8	30.6	14.3	3.1	196	33.1	21.6	22.3	18.8	4.2	287
Chicago (Morse, n.p.):												
Sons of University staff and boys from Hyde Park Neighborhood House ²	40.0	14.3	31.4	2.9	11.4	35						
Settlement House and Boys' Club	36.7	10.2	28.6	12.2	12.2	49						
Total ¹	39.0	18.5	24.6	8.5	9.2	130						
California (Eichorn, n.p.):												
Average socio-economic status	59.6	18.2	10.1	8.1	4.0	99	28.3	26.7	14.7	15.7	14.7	191
Better than average socio-economic status	36.7	29.4	15.3	5.6	13.0	177	29.4	13.7	29.4	7.8	19.6	102
Poorer than average socio-economic status	32.0	28.1	25.0	10.2	4.7	128	45.5	13.4	4.5	23.2	13.4	112
Total ¹	40.0	24.5	20.0	8.2	7.3	550	35.0	20.3	13.8	16.1	14.9	523

¹ Includes children for whom the background was not reported.

² No differences were found in the distribution of these two samples.

XIII.—Appendix B.—Results of Covariance Analysis

COMPARISON OF DIFFERENT WEIGHT-FOR-HEIGHT CLASSIFICATIONS

Tables 21 to 24 present in detail covariance analysis for the four age groups, which were summarized in tables 8 and 11.

TABLE 21.—PRESCHOOL AGE INTERVAL: *Results of covariance analysis for comparison of the regression of heat production on weight for boys and girls¹ within the Normal and Slender weight-for-height classifications*

Sex	Source of variation	Deviations from regression	
		D.f.	Mean sq. ²
Boys	Pooled variation from individual regressions	192	3. 81
	Difference in regression coefficients	1	14. 56
	Variation from common regression	193	3. 86
	Difference in adjusted means	1	10. 86
Girls	Pooled variation from individual regressions	147	2. 77
	Difference in regression coefficients	1	11. 57*
	Variation from common regression	148	2. 83
	Difference in adjusted means	1	3. 96

¹ Data from Lewis *et al.* (1937); Duval (1942).

² * = Significant at the 5-percent level.

TABLE 22.—SCHOOL AGE TO PUBERTY AGE INTERVAL: *Results of covariance analysis for comparison of the regression of heat production on weight for boys and girls in different weight-for-height classifications*

Sex	Source of variation	Deviations from regression			
		For Normal and Slender	For Normal and Stocky	For Normal and Overweight	For Stocky and Overweight

New York City (Taylor, n.p.)

		D.f.	Mean sq. ¹	D.f.	Mean sq. ¹	D.f.	Mean sq. ¹	D.f.	Mean sq. ¹
Boys	Pooled variation from individual regressions			157	14. 08	138	12. 87	45	19. 46
	Difference in regression coefficients			1	49. 49	1	15. 25	1	. 07
	Variation from common regression			158	14. 31	139	12. 89	46	19. 04
	Difference in adjusted means			1	10. 14	1	56. 95*	1	86. 98*
Girls	Pooled variation from individual regressions			184	13. 55	175	14. 00	77	16. 74
	Difference in regression coefficients			1	10. 71	1	2. 61	1	1. 36
	Variation from common regression			185	13. 53	176	13. 94	78	16. 54
	Difference in adjusted means			1	19. 78	1	148. 59**	1	42. 72

New York City (Topper and Mulier, 1929a, 1929b, 1932)

		D.f.	Mean sq.	D.f.	Mean sq.	D.f.	Mean sq.	D.f.	Mean sq.
Boys	Pooled variation from individual regressions					47	10. 65		
	Difference in regression coefficients					1	13. 70		
	Variation from common regression					48	10. 71		
	Difference in adjusted means					1	699. 11**		
Girls	Pooled variation from individual regressions	53	14. 57			54	17. 26		
	Difference in regression coefficients	1	22. 11			1	102. 46*		
	Variation from common regression	54	14. 71			55	18. 81		
	Difference in adjusted means	1	180. 17**			1	1111. 83**		

See footnote on p. 97.

TABLE 22.—SCHOOL AGE TO PUBERTY AGE INTERVAL: *Results of covariance analysis for comparison of the regression of heat production on weight for boys and girls in different weight-for-height classifications*—Continued

Sex	Source of variation	Deviations from regression							
		For Normal and Slender		For Normal and Stocky		For Normal and Overweight		For Stocky and Overweight	
New York (Davenport, Renfroe, and Hallock, 1939)									
Boys-----	Pooled variation from individual regressions.	<i>D.f.</i>	<i>Mean sq.¹</i>	<i>D.f.</i>	<i>Mean sq.¹</i>	<i>D.f.</i>	<i>Mean sq.¹</i>	<i>D.f.</i>	<i>Mean sq.¹</i>
	Difference in regression coefficients			203	16. 91				
	Variation from common regression			1	7. 51				
	Difference in adjusted means			204	16. 86				
Girls-----	Pooled variation from individual regressions.			1	90. 91*				
	Difference in regression coefficients			137	12. 72	123	12. 69	34	12. 41
	Variation from common regression			1	28. 77	1	1. 21	1	8. 92
	Difference in adjusted means			138	12. 83	124	12. 60	35	12. 31
				1	90. 77**	1	318. 63**	1	62. 58*
Illinois and Ohio (Wang, 1934, 1939; Wang <i>et al.</i> , 1926, 1936)									
Girls-----	Pooled variation from Individual regressions.	36	6. 64						
	Difference in regression coefficients	1	. 34						
	Variation from common regression	37	6. 47						
	Difference in adjusted means	1	1. 98						
Illinois (Morse, n.p.)									
Boys-----	Pooled variation from individual regressions.	79	24. 64						
	Difference in regression coefficients	1	13. 54						
	Variation from common regression	80	24. 51						
	Difference in adjusted means	1	34. 21						
Colorado (Lewis, Kinsman, and Iliff, 1937; Duval, 1942)									
Boys-----	Pooled variation from individual regressions.	732	7. 89	590	7. 93				
	Difference in regression coefficients	1	5. 37	1	. 76				
	Variation from common regression	733	7. 89	591	7. 92				
	Difference in adjusted means	1	10. 38	1	4. 49				
Girls-----	Pooled variation from individual regressions.	453	6. 30	380	7. 23	369	6. 88	39	7. 82
	Difference in regression coefficients	1	64. 84**	1	. 17	1	77. 77**	1	33. 05*
	Variation from common regression	454	6. 43	381	7. 21	370	7. 07	40	8. 45
	Difference in adjusted means	1	9. 42	1	52. 00**	1	144. 88**	1	. 01
California (Eichorn, n.p.)									
Boys-----	Pooled variation from individual regressions.	294	13. 52	315	17. 12	280	15. 40	63	34. 70
	Difference in regression coefficients	1	93. 97**	1	69. 40*	1	142. 86**	1	23. 12
	Variation from common regression	295	13. 80	316	17. 29	281	15. 85	64	34. 52
	Difference in adjusted means	1	40. 22	1	147. 36**	1	22. 88	1	35. 72
Girls-----	Pooled variation from individual regressions.	107	11. 73	116	12. 07	109	11. 77	57	13. 66
	Difference in regression coefficients	1	. 89	1	17. 74	1	37. 06	1	4. 75
	Variation from common regression	108	11. 63	117	12. 12	110	12. 00	58	13. 50
	Difference in adjusted means	1	16. 39	1	67. 19*	1	35. 87	1	2. 30

¹ * = Significant at the 5-percent level; ** = significant at the 1-percent level.

TABLE 23.—POSTPUBERTAL AGE INTERVAL: *Results of covariance analysis for comparison of the regression of heat production on weight for boys and girls in different weight-for-height classifications*

Sex	Source of variation	Deviations from regression					
		For Normal and Stocky		For Normal and Overweight		For Stocky and Overweight	
New York City (Topper and Mulier, 1929a; 1932)							
Girls	Pooled variation from individual regressions	D.f.	Mean sq. ¹	D.f.	Mean sq. ¹	D.f.	Mean sq. ¹
	Difference in regression coefficients			28	13. 53		
	Variation from common regression			1	4. 43		
	Difference in adjusted means			29	13. 22		
				1	119. 70**		
New York (Davenport, Renfroe, and Hallock, 1939)							
Girls	Pooled variation from individual regressions	36	26. 88	32	19. 54	28	31. 63
	Difference in regression coefficients	1	8. 65	1	27. 05	1	64. 11
	Variation from common regression	37	26. 39	33	19. 77	29	32. 75
	Difference in adjusted means	1	21. 62	1	48. 08	1	48. 43
Michigan (Hoobler, n.p.)							
Girls	Pooled variation from individual regressions	72	18. 64	45	16. 15	69	14. 10
	Difference in regression coefficients	1	79. 83*	1	23. 76	1	3. 74
	Variation from common regression	73	19. 47	46	16. 32	70	13. 96
	Difference in adjusted means	1	67. 96	1	127. 79**	1	1. 98
Arizona (Thompson, n.p.)							
Girls	Pooled variation from individual regressions	73	19. 55				
	Difference in regression coefficients	1	13. 80				
	Variation from common regression	74	19. 47				
	Difference in adjusted means	1	7. 03				
Washington (Esselbaugh, n.p.)							
Boys	Pooled variation from individual regressions	54	27. 12				
	Difference in regression coefficients	1	41. 62				
	Variation from common regression	55	27. 39				
	Difference in adjusted means	1	28. 81				
Girls	Pooled variation from individual regressions	62	24. 36	64	17. 91	48	26. 82
	Difference in regression coefficients	1	31. 42	1	34. 64	1	. 01
	Variation from common regression	63	24. 48	65	18. 17	49	26. 28
	Difference in adjusted means	1	11. 80	1	2. 00	1	55. 02
California (Eichorn, n.p.)							
Boys	Pooled variation from individual regressions	145	28. 76				
	Difference in regression coefficients	1	39. 08				
	Variation from common regression	146	28. 83				
	Difference in adjusted means	1	36. 04				
Girls	Pooled variation from individual regressions	151	17. 75	171	20. 82	90	23. 11
	Difference in regression coefficients	1	. 59	1	24. 44	1	23. 53
	Variation from common regression	152	17. 63	172	20. 84	91	23. 12
	Difference in adjusted means	1	103. 40*	1	49. 80	1	. 01

¹ * = Significant at the 5-percent level; ** = significant at the 1-percent level.

TABLE 24.—GIRLS 16 YEARS AND OLDER AND BOYS 18 YEARS AND OLDER: *Results of covariance analysis for comparison of the regression of heat production on weight for different weight-for-height classifications*

Sex	Source of variation	Deviations from regression					
		For Normal and Stocky		For Normal and Overweight		For Stocky and Overweight	
New York (Davenport, Renfroe, and Hallock, 1939)							
Girls	Pooled variation from individual regressions	<i>D.f.</i>	<i>Mean sq.¹</i>	<i>D.f.</i>	<i>Mean sq.¹</i>	<i>D.f.</i>	<i>Mean sq.¹</i>
	Difference in regression coefficients			29	14. 55		
	Variation from common regression			1	2. 29		
	Difference in adjusted means			30	14. 14		
				1	236. 66**		
Ohio (McKay, 1930)							
Girls	Pooled variation from individual regressions	42	14. 49	38	15. 76	36	15. 30
	Difference in regression coefficients	1	1. 22	1	1. 42	1	5. 98
	Variation from common regression	43	14. 18	39	15. 39	37	15. 05
	Difference in adjusted means	1	21. 59	1	16. 73	1	. 38
Michigan (Hoobler, n.p.)							
Girls	Pooled variation from individual regressions	31	17. 16	38	12. 37	43	11. 65
	Difference in regression coefficients	1	10. 78	1	3. 54	1	5. 90
	Variation from common regression	32	16. 96	39	12. 15	44	11. 52
	Difference in adjusted means	1	2. 54	1	. 89	1	33. 55
Arizona (Thompson, n.p.)							
Boys	Pooled variation from individual regressions	32	17. 81				
	Difference in regression coefficients	1	7. 42				
	Variation from common regression	33	17. 50				
	Difference in adjusted means	1	61. 04				
Girls	Pooled variation from individual regressions	173	18. 69	150	18. 01	99	20. 11
	Difference in regression coefficients	1	27. 30	1	1. 46	1	10. 26
	Variation from common regression	174	18. 74	151	17. 90	100	20. 01
	Difference in adjusted means	1	75. 14*	1	68. 55	1	. 76
California (Eichorn, n.p.)							
Girls	Pooled variation from individual regressions	74	16. 30	79	16. 40	43	15. 33
	Difference in regression coefficients	1	5. 71	1	15. 73	1	1. 88
	Variation from common regression	75	16. 16	80	16. 39	44	15. 02
	Difference in adjusted means	1	32. 66	1	47. 93	1	2. 77

¹ * = Significant at the 5-percent level; ** = significant at the 1-percent level.

COMPARISON OF REGRESSION COEFFICIENTS

The analysis of covariance of the regression coefficients for boys and for girls are given in table 25. Analysis of covariance of the regression coefficients within regions are given in table 26 for children (boys and girls combined) within the Preschool and School Age to Puberty age interval and in table 27 for boys and girls within the Postpubertal age interval.

TABLE 25.—REGRESSION COEFFICIENTS FOR BOYS AND FOR GIRLS: *Results of covariance analysis*

Location	Investigator(s) ¹	Source of variation	Deviations from regression	
Preschool age interval; Normal weight-for-height classification				
New York City	Taylor (n.p.)	Pooled variation from individual regressions	<i>D. f.</i> 16	<i>Mean sq.</i> ² 2.36
		Difference in regression coefficients	1	4.23
Texas	Lamb (n.p.)	Pooled variation from individual regressions	30	4.10
		Difference in regression coefficients	1	2.73
Colorado	Lewis <i>et al.</i> (1937); Duval (1942).	Pooled variation from individual regressions	343	3.44
		Difference in regression coefficients	1	11.87
School Age to Puberty age interval; Normal weight-for-height classification				
New York City	Taylor (n.p.)	(Not tested as the regression coefficients were approximately the same.)		
Do	Topper and Mulier (1929b, 1932).	Pooled variation from individual regressions	92	14.62
		Difference in regression coefficients	1	146.03**
New York	Davenport <i>et al.</i> (1939)	Pooled variation from individual regressions	297	15.69
		Difference in regression coefficients	1	33.26
Do	Webster <i>et al.</i> (1941)	Pooled variation from individual regressions	98	17.89
		Difference in regression coefficients	1	28.58
Illinois and Ohio	Wang (1934, 1939); Wang <i>et al.</i> (1926, 1936).	Pooled variation from individual regressions	50	7.12
		Difference in regression coefficients	1	9.26
Illinois	Morse (n.p.)	Pooled variation from individual regressions	101	22.90
		Difference in regression coefficients	1	84.14
Michigan	Maroney and Johnston (1937).	Pooled variation from individual regressions	23	7.70
Do	Hoobler (n.p.)	Difference in regression coefficients	1	27.29
		(Not tested as the regression coefficients were approximately the same.)		
Texas	Lamb (n.p.)	Pooled variation from individual regressions	39	4.10
		Difference in regression coefficients	1	1.94
Colorado	Lewis <i>et al.</i> (1937); Duval (1942).	(Not tested as the regression coefficients were approximately the same.)		
California	Eichorn (n.p.)	Pooled variation from individual regressions	405	13.29
		Difference in regression coefficients	1	30.48
School Age to Puberty age interval; Overweight weight-for-height classification				
New York City	Taylor (n.p.)	Pooled variation from individual regressions	126	18.22
		Difference in regression coefficients	1	92.56*
Do	Topper and Mulier (1929a, 1932).	Pooled variation from individual regressions	58	39.40
		Difference in regression coefficients	1	16.89
New York	Davenport <i>et al.</i> (1939)	(Not tested as the regression coefficients were approximately the same.)		
New York City	Bruch (1939a and b; 1942)	Pooled variation from individual regressions	24	29.23
		Difference in regression coefficients	1	45.09
Colorado	Lewis <i>et al.</i> (1937); Duval (1942).	Pooled variation from individual regressions	87	7.98
		Difference in regression coefficients	1	54.17*
California	Eichorn (n.p.)	(Not tested as the regression coefficients were approximately the same.)		
Postpubertal age interval; Normal weight-for-height classification				
New York	Davenport <i>et al.</i> (1939)	Pooled variation from individual regressions	34	19.73
		Difference in regression coefficients	1	36.81
Colorado	Lewis <i>et al.</i> (1937); Duval (1942).	Pooled variation from individual regressions	36	13.87
		Difference in regression coefficients	1	106.10**
Washington	Esselbaugh (n.p.)	Pooled variation from individual regressions	84	26.89
		Difference in regression coefficients	1	130.42*
California	Eichorn (n.p.)	Pooled variation from individual regressions	261	23.43
		Difference in regression coefficients	1	160.89**
Postpubertal age interval; Overweight weight-for-height classification				
New York	Davenport <i>et al.</i> (1939)	Pooled variation from individual regressions	40	32.60
		Difference in regression coefficients	1	9.01
Washington	Esselbaugh (n.p.)	Pooled variation from individual regressions	74	23.54
		Difference in regression coefficients	1	1.43
California	Eichorn (n.p.)	Pooled variation from individual regressions	118	23.73
		Difference in regression coefficients	1	28.27

¹ For Literature References, see section XI.² * = Significant at the 5-percent level; ** = significant at the 1-percent level.

TABLE 26.—WITHIN REGION COMPARISON OF THE REGRESSION COEFFICIENTS FOR CHILDREN ¹ WITHIN THE PRESCHOOL AND SCHOOL AGE TO PUBERTY AGE INTERVALS: *Results of covariance analysis*

Region	Source of variation	Deviations from regression		
All locations-----	Preschool age interval; Normal weight-for-height classification			
	Pooled variation from individual regressions-----	<i>D.f.</i> 395	<i>Mean sq.</i> ² 4. 33	
	Difference in regression coefficients-----	2	10. 00	
	School Age to Puberty age interval; Normal weight-for-height classification			
	Pooled variation from individual regressions-----	2785	13. 06	
	Difference in regression coefficients-----	14	148. 12**	
	Northeast-----	Pooled variation from individual regressions-----	790	17. 08
	Difference in regression coefficients-----	4	194. 84**	
	North Central-----	Pooled variations from individual regressions-----	291	16. 58
	Difference in regression coefficients-----	4	60. 50**	
Western and Texas-----	Pooled variation from individual regressions-----	1704	10. 60	
	Difference in regression coefficients-----	4	176. 98**	
	School Age to Puberty age interval; Overweight weight-for-height classification			
All locations-----	Pooled variation from individual regressions-----	552	24. 17	
	Difference in regression coefficients-----	8	12. 98	

¹ Data for boys and girls were combined within locations; see table 17.

² **=Significant at the 1-percent level.

TABLE 27.—WITHIN REGION COMPARISON OF THE REGRESSION COEFFICIENTS FOR BOYS AND GIRLS WITHIN THE POSTPUBERTAL AGE INTERVAL: *Results of covariance analysis*

Region	Source of variation	Boys		Girls		
		Deviations from regression		Deviations from regression		
All locations----- Northeast and North Central. Western-----	Normal weight-for-height classification					
	Pooled variation from individual regressions-----	<i>D.f.</i> 228	<i>Mean sq.</i> ¹ 28. 12	<i>D.f.</i> 372	<i>Mean sq.</i> ¹ 17. 29	
	Difference in regression coefficients-----	4	109. 94**	10	32. 64*	
	Pooled variation from individual regressions-----	32	27. 81	133	18. 38	
	Difference in regression coefficients-----	1	47. 20	6	12. 17	
	Pooled variation from individual regressions-----	196	28. 17	239	16. 68	
	Difference in regression coefficients-----	2	60. 26	3	42. 15	
	Overweight weight-for-height classification					
	Pooled variation from individual regressions-----	72	25. 77	344	22. 55	
	Difference in regression coefficients-----	3	27. 71	8	29. 43	

¹ *=Significant at the 5-percent level; **=Significant at the 1-percent level.

